ИЗМЕРИТЕЛЬНАЯ
ТЕХНИКА

Number 2

February 1959

SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

■ This translation of a Soviet journal on instrumentation is published as a service to American science and industry. It is sponsored by the Instrument Society of America under a grant in aid from the National Science Foundation with additional assistance from the National Bureau of Standards.

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

■ This translation of the Soviet Journal *Izmeritel'naya Tekhnika* is published and distributed at nominal subscription rates under a grant in aid to the Instrument Society of America from the National Science Foundation. This translated journal, and others in the Series (see back cover), will enable American scientists and engineers to be informed of work in the fields of instrumentation, measurement techniques, and automatic control reported in the Soviet Union.

The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis, permitting readers to appraise for themselves the scope, status, and importance of the Soviet work.

Publication of *Izmeritel'naya Tekhnika* in English translation started under the present auspices in August, 1959, with Russian issue No. 1 of Jan.-Feb. 1958. The six issues of the 1958 volume year were published in English translation by February, 1960. Russian issue No. 1 of January, 1959 will be published in March, 1960, and the twelve issues of 1959 will be published in English translation by December, 1960.

Transliteration of the names of Russian authors follows the system known as the British Standard. This system has recently achieved wide adoption in the United Kingdom, and is being adopted in 1959 by a large number of scientific journals in the United States.

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1959 Issue Subscription Prices:

Per year (12 issues), starting with 1959, No. 1

General: United States and Canada	\$25.00
Elsewhere	28.00
Libraries of nonprofit academic institutions:	
United States and Canada	\$12.50
Elsewhere	15.50
Single issues to everyone, each	\$ 6.00

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Subscriptions and requests for information on back issues should be addressed to the:

Instrument Society of America
313 Sixth Avenue, Pittsburgh 22, Penna.

Translated and printed by Consultants Bureau, Inc.

Number 2—February, 1959

English Translation Published April, 1960

Measurement Techniques

The Soviet Journal Izmeritel'naya Tekhnika in English Translation

Reported circulation of the Russian original 8,000.

Izmeritel'naya Tekhnika is an organ of the Academy of Sciences, USSR

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MEASUREMENT TECHNIQUES

1959, Number 2 February

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THE IMPOSING PROGRAM OF BUILDING COMMUNISM ON A BROAD FRONT, AND THE TASK OF THE WORKERS IN METROLOGY

The Soviet people and the working masses of all countries followed with great interest the work of the 21st Congress of the Communist Party of the Soviet Union. This Congress marks the entry of our country into a new historical period of the development, the period of building the Communist society on the broad front. The historical decisions of the Congress present the schedule of work for the Party and the entire Soviet people for the next seven years.

The principal objective of the Seven-Year Plan of development of the national economy of the USSR for 1959-65 is the further vigorous expansion of all branches of the economy; this is based predominantly on the growth of heavy industry, and the considerable strengthening of the economic potential of the country, with the object of ensuring a continuous rise in the living standard of the population. In fulfilling this plan a decisive step forward will be made in the creation of the technical and raw material basis for Communism and for the realization of the principal economic objective of the USSR, i.e., the overtaking and surpassing, within an historically short period, of the most advanced capitalist countries in production per head of population. The increasing material and spiritual needs of the Soviet people must be satisfied more completely.

In the next seven years the country will increase the production of industrial goods by 80%, including an increase in the production of means of producing by 85-88%. During the seven-year period, it is planned to double the output of the engineering of metal-working industries. High rates of development are scheduled for heavy machine construction, instruments, electronics, electrical engineering, machine tools and tool making. The total output of the agricultural industry must be increased 1.7 times. According to the new Seven-Year Plan the output of instruments in 1965 must exceed that of 1958, 2.5-2.6 times.

The next seven years will, in all parts of the country, and in particular in the eastern part, be a period of construction the like of which has never been seen before. The volume of public investment will increase during 1959-65 to 1940-1970 billion rub. or 1.8 times more than in the preceding seven years. This is almost as much as the total investment in the national economy during the years of Soviet government.

The Seven-year Plan is an indication of the sincere desire of the Communist Party to improve still further the life of the Soviet people. This is evident from the increase in the production of consumer goods, in the construction of houses for the workers, and also in the reduction of the working day and the increase in wages, especially of the lower paid categories of workers and office personnel, and in the increase of pensions, and many other measures of a similar kind.

The Seven-Year Plan provides for extensive measures in the development of education, science, and culture. The number of pupils in primary and high schools will increase in 1965 to 38-40 million as compared with 30 million in 1958. In 1959-1965 the universities will produce 2,300,000 specialists. The necessary conditions will be created for an even more rapid development of all branches of science, for important theoretical research and for great new scientific discoveries. The state will allocate large funds to the construction of new scientific institutes and for the most up-to-date equipment for institutes and laboratories.

A big role will be played by metrologists in the realization of the fast program of works revealed by the plan figures. The introduction of new up-to-date equipment, complete automation and mechanization, electronics, nuclear power, rocket engineering, etc., is not possible without modern precision measurement devices and the use of modern measuring techniques and will require further development work in the field of measurements. The uniformity of workpieces, and the accuracy and correct use of measures and measuring devices are the indispensible prerequisites for the organization of modern industrial production in all branches of the national economy.

In metrology the most important work must be carried out on the improvement of standard measures and increasing their precision, and also on the expansion of the range of accurate measurements for both very large and very small dimensions.

The adoption of the wavelength of light as a standard of length must be completed and the accuracy of standard measures for linear measurements improved 10-100 times. The introduction of molecular and atomic standard measures must increase the accuracy of the standard measurements of time and frequencies not less than 100 times. Work will be completed on the accurate measurement of the hydromagnetic ratio of the proton and on the use of this constant for the new standard measures of electric and magnetic units. Up-to-date standard measures are to be developed for the ionizing radiations and particles, including the standards of the neutron flux.

Due to the modern development of science and technology the Soviet metrologists are faced with the very important problem of expanding the measuring range of master and reference gages for large and small masses, large forces, super-high pressures,high vacuum, high and very low temperatures, strong currents and high voltages, very high frequencies, ionizing and infrared and ultraviolet radiations.

Investigation must be carried out on measurements in special, nonstationary conditions, during dynamic processes, at high accelerations, and at high and very low temperatures.

The problem of automatic measurement, the use of modern electronic-computer techniques in metrology; the transition from the metrology of indicating devices to the metrology of automatic recording and control devices require investigation.

Important tasks are facing us in the field of theoretical metrology. The knowledge accumulated on the individual types of measurements requires generalization, expecially in view of and taking into account the latest achievements of mathematical science in the field of mathematical statistics and the theory of probability, and also of the development of electronic computers. On the other hand, such fundamental metrological problems as the rational balance between the accuracy of the master devices and the devices of measures being checked, the methods of determining the errors of measurements (and inspection), the methods of evaluation of complex tests when the laws governing the distribution of components are known and when they are not known, the assessment of the errors of individual links and chains of measures and devices of complete plants, the methods of the advance assessment of errors of measuring equipment under construction etc. await solution.

All these problems must be solved by the metrical metrological scientific research institutes of the Commission of Standards, Measures and Measuring Devices in Leningrad, Moscow, Mendeleevo (Moscow regional), Kharkov, Novosibirsk, and Sverdlovsk. In a number of metrological institutes new laboratories equipped with modern scientific devices are under construction.

The ever-expanding use of measuring techniques in the national economy presents important problems to the State Inspection Laboratories for Metrology.

These problems include the maintenance of the uniformity and correctness of measures and measuring devices in a given territory, cooperation in the introduction of new advanced measuring methods and in the automation and mechanization of production processes, inspection of the properties of devices in operation,carrying out the systematic testing of devices produced by the instrument factories of the Council of the National Economy, to whose region they belong, and the provision of scientific and technical information on measuring methods.

Between 1959 and 1965 new buildings will be errected for a number of State Inspection Laboratories for Metrology, especially in the Eastern and South-Eastern parts of the country, and the nomenclature of the master gases in the equipment of these laboratories will be increased.

Important problems are facing metrology workers in the field of instrument construction.

Alongside with an increase in the production of the equipment greater qualitative changes will take place in the nomenclature of the devices being produced, obsolete gages will be replaced by more modern equipment, their number will be increased by developing inspection equipment and systems of devices based on new principles involving the use of electronics, semiconductors, ultrasonics, radioisotopes, infrared radiation, mass spectrometry, etc.

Designs of devices will be developed which record the quantity numerically and are combined with electronic computers.

In the field of temperature measurements infrared pyrometers will be developed for measuring temperatures of nonluminous bodies, as well as the combined light-optical pyrometers for measuring the selective radiations at high temperatures.

For measuring and the control of the flow of gases, liquids and steam, gyroscopic, electromagnetic, ultrasonic, and tachometrical devices will be built, while for granular materials these devices will be based on the rotation principle.

In the field of pressure measurements new models of precision devices for measuring draft and pressures will be developed, as well as devices for measuring and regulating pressure and vacuum, based on the use of radioactive radiation sources and of electric audio vibrations.

Large-scale production will be organized of the devices for the chemical industry intended for the control of the complex composition of various substances during their production process, which will be based on new methods. They include devices founded on the use of the selective absorption of the infrared and ultraviolet regions of the spectrum by various substances, mass spectrometers, photospectrometers, optical-acoustic, thermochemical, and magnetic gas analyzers.

For electrical measurements, discrete-action devices, transistor devices, and electronic phase meters and wattmeters will be produced.

For the accurate measurement of large components devices will be developed which are based on the use of geodetic methods and the interference of microradiowaves, and also devices based on the electromagnetic principle for measuring angles.

For measuring mass, extensometer balances will be put into production as well as balances based on the magnetoelectric principles of balancing; they will incorporate electronic amplifiers and servomechanisms.

A considerable increase of measurement ranges and of the accuracy of indications of measuring devices is scheduled.

The metrological institutes of the Committee must ensure a high scientific and technological standard of optical inspection of measures and measuring devices developed by the instrument industry, and of the new advanced measuring equipment which is now being put into use by the national economy.

The Seven-Year Development Plan of the National economy of the USSR for 1959-65 is a new essential stage in the life of the Soviet Union, which has entered the period of the construction of the Communist Society on a broad front.

Soviet metrologists, instruments makers, and workers in inspection establishments will all make their valuable contribution to the fulfilment of the great tasks set by the Seven-Year Plan.

THE 1958 SESSION OF THE INTERNATIONAL COMMITTEE OF WEIGHTS AND MEASURES

G. D. Burdun

The ordinary session of the International Committee of Weights and Measures, which took place in Sévres from September 29th to October 4th, 1958, was attended by the following 15 (out of 18) member nations of the Committee: Australia, Austria, Great Britain, Germany, Holland, Spain, Italy, Canada, USSR, USA, France, Sweden, and Japan.

The major part of the session was taken up by the questions relating to the ordinary 11th General Conference of Weights and Measures which will take place in 1960 and which will consider such important problems as the revision of the Meter Convention, the adoption of a new definition for the meter in wavelengths of light, a more accurate definition of the International Temperature Scale, etc.

In his address, the Secretary of the Committee, Professor Cassini (Italy) gave information about: the changes in the composition of the Committee which had taken place since the previous session (the election by post of K. Krishman, the Director of the National Physical Laboratory of India, to be member of the Committee in place of S. Statescu, Rumania, who had died; and the death of the honorary member of the committee, Professor M. A. Chatelain), the sessions of the consultative committees, and the financial activities during September 1st, 1956 to August 31, 1958.

In his detailed address the Director of the International Bureau of Weights and Measures Ch. Volais and the reports of the members of the Bureau gave information about international work on metrology, and on some research works carried out by the Bureau during the past two years.

The laboratories of the Bureau carried out the checking of the standard meters and kilograms of a number of countries including the national standard-copies, the national standards of the USSR – the No. 11 meter and No. 26 kilogram.

These checks produced the following results:

Year	No. 11 standard meter	No. 26 standard kilogram
1889	1 m-0.54 mk	1 kg-0.032 mg
1957	1 m-0.45 mk	1 kg-0.016 mg

Certificates were also issued for a considerable number of geodetical tape measures for the Chinese People's Republic.

The density of mercury was determined again and produced the value 13.56948 at a temperature of 17.7°C with an error of the order of $20\text{-}30 \cdot 10^{-6}$.

Promising work is being carried out at the Thermometry Laboratory on the development of precision mercury thermometers from melted quartz.

In the Electricity Laboratory regular checks were made of standard resistance coils and of standard cells of eight countries: Great Britain, the German Democratic Republic, Canada, USSR, USA, the Federal German Republic, France, and Japan, against the standards of the International Bureau.

These comparisons and corrections produced the following deviations of the national electrical standards from the standards of the International Bureau:

Country	Standard ohm		Standard volt
Great Britain	−3.4 $\mu\Omega$		+5.2 μv
The German Democratic Republic	0.0 "	(corrected value)	+1.2 "
Canada	−4.8 "		−0.8 "
USSR	+0.4 "		+8.4 "
USA	−1.0 "		−1.3 "
The German Federal Republic	+3.3 "		+0.2 "
France	−7.4 "		−2.1 "
Japan	−0.4 "		−3.4 "

The Electricity Laboratory carried out research work on the development of a standard ohm from pure metals (platinum and mercury) in vessels at the triple point of water. The standard resistance coils of chromium-gold received in 1951 from the German Democratic Republic showed a good stability. These coils proved more stable in time than manganin coils.

The International Bureau completed the absolute measurements of acceleration due to gravity by the method of free fall; these measurements lasted for several years. The results produced a correction of g −12.8 milligal to the Potsdam value. Since a number of other laboratories have carried out and are continuing the measurement of g the need arises to consider at the 11th General Conference of Weights and Measures in 1960 the question of the constants, which is of great importance for metrology.

In 1957 the International Bureau carried out the checking of photometric lamps from Great Britain, the German Democratic Republic, Canada, USSR, USA, the Federal German Republic, France and Japan. An agreement within 0.5% was found between the light standards of these countries and that of the International Bureau.

The Vice-Director of the Bureau, Professor Terrien reported about an extensive completed research work on interference measurements. New interferometric investigations were carried out which were concerned with the spectral qualities of the best radiation of Kr^{85} and Hg^{198}. For this purpose and also for measuring the wavelength of these radiations in terms of the red cadmium line, the Michelson interferometer was found to be more accurate than the Fabry-Perot Interferometer, especially after some modifications, including the alteration of the photoelectrical system for the indication and recording of the intensity of the interference fringes. The results obtained were passed on to the Consultative Committee on the Definition of the Meter. This work produced experimental support for the selection of the orange line of Kr^{86} for the definition of the meter because of its better metrological properties.

Other researches now in progress include the investigation of an interference mano-barometer, the making and checking of optical photoelectrical comparators,and the experiments on the accurate measurement of the refractive index of air by means of a small interference refractometer.

The photoelectric comparator which is on order for the Geneva Physical Society will be fitted with the interferometer made at the Bureau. The Michelson interferometer will be used in direct measurements in wavelengths of gage rods with graduations, end gages, and precision scales. It is intended to make a vibration-free stable support and heat-insulated casing with constant pressure and temperature, in order to ensure the stability and uniformity of atmosphericc conditions during the interference measurement of standard lengths.

Ch. Volais reported about a program of international metrological investigations scheduled for the near future. This program includes:

1. Checking of color temperature standards;
2. Checking of standard end gages of up to 1 m in length;
3. Checking of standards of capacity;
4. Work on atomic beams for interference measurements;
5. Determination of the refractive index of air;

6) Determination of the densities of mercury and water;

7) Work on the determination of acceleration due to gravity.

The International Committee of Weights and Measures also heard the papers of the representatives of the Consultative Committees on the Definition of the Meter, on the Definition of the Second, on Thermometry, on Electricity and on Photometry, and of the Committee on the Revision of the Meter Convention.

The Consultative Committee on the Definition of the Meter tabled for discussion the draft resolution regarding the adoption of the new definition of the meter which is based on a natural standard which is to replace the platinum-iridium International prototype. After a prolonged discussion the International Committee adopted two draft resolutions which must be approved by the 11th General Conference of Weights and Measures which takes place in 1960.

Draft resolution 1. The 11th General Conference of Weights and Measures, taking into account the fact that the International Prototype fails to define the meter with an accuracy which satisfies the present-day requirements of metrology, and that at the same time it is desirable to fix a natural and indestructible standard, decides:

1) that the meter is a length equal to 1650763.73 wavelengths of the radiation in vacuum corresponding to the interval between the levels $2p_{10}$ and $5d_5$ of the krypton 86 atom;

2) that the definition of the meter in force since 1889, which is based on the platinum-iridium International Prototype is abolished.

Draft resolution 2. The 11th General Conference of Weights and Measures invites the International Committee:

1) to work out instructions on the practical introduction of the new definition of the meter;

2) to continue the research on the improvement of standards of length.

The representative of the Consultative Committee on the Definition of the Second stated that the new definition of the second adopted by the International Committee in 1956 was noted with satisfaction by the International Astronomical Union at its General Assembly in Moscow in August 1958.

The Consultative Committee on Thermometry considered the question of the fixed points of the International Temperature Scale.

The International Committee approved the proposals of the Consultative Committee on the extension of the International Temperature Scale in the direction of higher temperatures and on the investigation of optical pyrometers. The Committee supported the proposal concerning the remaining of the International Temperature Scale as the Practical Temperature Scale, in order to avoid confusion between the degree of this scale and the temperature unit of the International System of Units.

The International Committee approved the report of the Chairman of the Consultative Committee on Electricity on the work which is being carried out on the absolute measurements and on the international comparison of electrical units, and agreed to the extension of the periods between the international comparisons to three years instead of the present two, and decided to perform the next comparison in 1960 after the General Conference of Weights and Measures. In addition, the International Committee has directed the Consultative Committee to study the results of the investigations into the gyromagnetic deviation of the proton which are now carried out by international metrological institutes.

The Consultative Committee on Photometry worked on the primary standards of light flux, discussed the results of international comparisons and of the work on the standardization of units of light. The international Committee approved the intention of carrying out international comparisons of color temperature standards and of the spectrophotometrical comparisons of standard lamps. It was decided to compare the photometric standards every four years.

In connection with the need to organize international comparisons of radioactive standards, which was suggested by many international organizations, the Committee adopted the resolution on the formation of the new Consultative Committee on Standards for Measuring Ionizing Radiations. The resolution adopted by the International Committee on this question reads as follows:

"The International Committee, after being informed of the ever-increasing need felt by national institutes and various other scientific organizations for the improving of the international situation with regard to the coordination of standards for measuring ionizing radiations, and recognizing that these needs could be met by expanding the activities of the International Bureau, decides to set up the Consultative Committee on Standards for Measuring Ionizing Radiations, whose direct task would be to devise a program of work for the International Bureau and to compile a list of equipment and personnel and to estimate the cost of this equipment and of the work, and directs the Consultative Committee to present its report to the International Committee on or before July 1st, 1959."

Professor A. Astin, the Director of the National Bureau of Standards of the USA was elected chairman of the new Consultative Committee.

The Committee on the Revision of the Meter Convention presented for consideration by the International Committee, two drafts of the amendment to the Convention, one of which provides for its complete replacement and the other amends some paragraphs, mainly in the regulations appended to the Convention.

The International Committee was generally in favor of a minimum number of amendments to the text of the Convention. The committee considered point by point the texts of the Convention, and the Appendix, and adopted the proposals concerning the amendment of a number of clauses concerning, in particular, the extension of the activities of the International Bureau, the fixing of the yearly subscriptions of states-members of the Convention for the maintenance of the International Bureau, the order of voting the resolutions of the Committee and the General Conference, and the replacement of half of the members of the International Committee. The International Committee instructed the Consultative Committee to work out, on the basis of discussion, a new draft of the amendment which will be discussed at the session of the Committee on the Revision of the Meter Convention in the Spring of 1959 and subsequently presented to the International Committee for approval.

The International Committee approved the estimates of the Internal Bureau for 1959-60 and adopted the resolution on the reduction of the initial subscription of states joining the Meter Convention. The International Committee also adopted the resolution on prefixes for multiple and sub-multiple units and on the abridged designation of the International system of units by the symbol SI. A resolution was also adopted summoning the 11th General Conference of Weights and Measures on October 11th, 1960.

PREPARING FOR THE NEW FORMS OF GOVERNMENT INSPECTION IN THE FIELD OF MEASUREMENTS*

B. L. Sokolov

In connection with the decision of the Committee of Standards, Measures, and Measuring Devices concerning the postponement of the introduction of Regulations 12-58, the Committee and its local branches must, in 1959, carry out the measures necessary for the change-over to the new forms of government inspection in the field of measurements given in Regulations 12-58.

It appears useful to state our considerations on several problems which in our opinion call for a speedy solution.

Technical equipment and its improvement. The three-year plan 1955-1958 for the supply of inspection equipment to the local branches of the Committee provided for the fitting-out of laboratories and permanent branches with complete inspection equipment which may be needed in checking all types of gages and devices used by the plants and organizations of the industry in the region allocated to the particular branch of the Committee. Although the equipment of laboratories has been substantially improved, the shortcomings are still very great. Many items scheduled for delivery have not been supplied and a number of laboratories are still short of

*Published for discussion.

inspection equipment. This situation seriously endangers the full adoption of the new system of government inspection.

In accordance with the new Regulations the government inspector who supervises a number of districts must carry out as many inspections as possible at the actual places where the devices are used, and should not be satisfied by merely ascertaining the presence or absence of the inspection stamp on the device but must perform a complete checking of its scale. The use for this purpose of equipment mainly intended for stationary work failed to produce the intended results. What is needed are small portable sets suitable for transportation in a car. However, the development of portable inspection equipment has hardly started; the All-Union Scientific Research Institute of the Committee designed a portable device for testing three-phase ac meters, of which only one prototype has actually been made.

The dates fixed by the Committee for the production of this equipment to the designs of institutes and inspection laboratories (1959-62) are too far and at the same time unrealistic, since the institutes and laboratories have not yet started the development of these designs. The institutes and laboratories should work out the technical specifications for these devices and plants, and, if possible, prepare the models.

At present the state inspection laboratories have at best only one set of the required inspection equipment; the government inspectors who are charged with supervision in their districts are unable to inspect the gages and to check their actual conditions, accuracy and the need of repair, with the exception of devices used for weights measurements, at the places where they are used.

An essential point is the amendment of the instructions of the Committee concerning the inspection of gages, in order to take portable equipment into account. This is necessary because often it is not possible to carry out at the places where the devices are used inspection operations which are, however, easy to perform in a permanent laboratory.

Instructions should also be devised which provide for a simplification of the inspection process (especially so far as routine inspection is concerned) and for the omission of some elements of the inspection.

Finally, a clear decision is required concerning the size of permissible errors for the new devices, equipment in use, and devices due to be inspected. It is obvious that the permissible indication errors of a new device cannot be maintained throughout its service life. However, at present, in many instructions the requirements concerning the permissible errors of the new devices and of the devices in use are the same.

It is desirable to improve the precision of a number of gages made by the industry and to fix a uniform, slightly greater permissible error for the devices in use and those being inspected, since in effect there is no difference between the inspection of devices at the workplace and their testing, involving the actual checking of indications. It should be permitted, if the owner so desires, to mark – after inspection – the devices which satisfy the requirements of the instructions, by the application of the official inspection stamp.

In the case of a number of gages, the limits of permissible errors should be extended. For instance: the extension of tolerances of gas meter indication errors had no effect upon the operation of meters and the measurement of the gas, but it considerably reduced the number of meters requiring repair and regulation; the result was a considerable saving.

It is natural, in this connection, that the special design features of devices, their field of application, the type of measurements they perform and the required accuracy should be taken into account.

The new forms of government inspection laid down in Regulations 12-58 call for the highest independence in the work of the staff of state inspection laboratories, thus making a wide use of personal initiative possible for them. The inspectors should be given the right to decide on the suitability of a gage for further use, even if the accuracy of its indication is ensured only within the range of the vernier scale of the dimensions in which the measurements are actually made. There is no need to require an absolute compliance of the gage with the requirements of the instruction over its entire scale, vernier etc., if it is certain that the gage is only used for measurements restricted to a certain section of the scale or the vernier. This will considerably reduce the number of gages rejected during the inspection or checking, cut the costs for the maintenance and replacement of measuring instruments and alleviate the shortage of a number of gages.

There is a need for a strict organization at the institutes of the Committee of the inspection, repair, and adjustment of master gages and devices belonging to the state inspection laboratories.

The institutes should check the gages rapidly, and, as a rule, in the presence of the representative of the state inspection laboratory who brought them. It would be useful to create at the institutes a loan stock of some devices which could be issued in place of the equipment left for inspection or repair. As a result, the industrial plant would have no difficulties because their gages are held at the state inspection laboratories for checking or repair unduly long.

It is desirable that the institutes should consider the inspection by the 1st class state inspection laboratories of some master devices of the neighboring 2nd and 3rd class state inspection laboratories. This would reduce the expenses of these laboratories, and speed up the inspection process.

It is extremely important to organize at the repair-experimental workshops (REW) of the institutes, the repair of reference and master devices of all types belonging to the state inspection laboratories. It is entirely wrong that the REW of institutes do not accept for repair the widely used columns of plunger-loaded pressure gages of all ranges and classes, master dynamometers, etc.; as a result this, valuable inspection equipment cannot be used, and in several regions of the country many inspections needed by industry are not being carried out.

The practice of lowering the class of master devices, or repairing many gages at outside organizations or sub-contractors when these devices cannot be repaired at the REW, which is now widely followed by the institutes, should be abandoned since in such cases the equipment is held in repair for an excessively long time and the cost of such repairs is very high.

It would be useful if the various REW of institutes specialized in the repair of certain types of references and master gages. This would help to reduce the cost and labor involved in the repair; for example, it would be possible to use parts of the rejected columns of some instruments in the repair of others, thus reducing the cost.

It is necessary to create a clear system of servicing the state inspection laboratories by the adjustment specialists of the Committee's Bureau of Interchangeability, in order to perform the adjustments of optico-mechanical devices and of the reference devices for weight measurements in situ. The travelling teams of adjusters will prevent damage to expensive equipment whose repair and adjustment is often entrusted to incompetent operators. It would be useful, taking as the example the already existing system of technical inspection of the measuring equipment in industry, to set up within the organization of the Committee a system of technical inspection which would carry out on the basis of a definite plan the preventive repairs of opticomechanical devices and precision balances.

Personnel. The quality and the qualifications of the personnel are factors of decisive importance in completing the tasks facing the state inspection laboratories.

During the past three years there has been a considerable improvement in the staff of laboratories. However, the inspection of measuring equipment where they are used and the testing of devices with the actual checking of indications of their scales, call for radical changes in the principles upon which the training of the technical personnel has been based. A government inspector must be able to check many types of devices used in various fields of measurements. It is, therefore, necessary to reorganize the technical training in laboratories in order to enable prospective inspectors to study the subjects related to their main subject (at least by learning how to check all widely used gages).

It would be useful to organize at the Odessa Metrology College, and also at the scientific research institutes of the Committee, permanent one-or two-month courses for increasing the qualifications of the technical staff of the laboratories. For training technicians with a wider background it is necessary to alter the syllabus of the Metrology College.

The organization of special courses for increasing the qualifications of technical personnel will affect the training of inspectors and the syllabus of the external examination for the diploma of the Senior Government Inspector.

The whole system of courses for government inspectors calls for a re-examination. All general subjects should be dropped from the syllabus and instead a number of hours devoted to teaching the theoretical foundations of metrology and to increased practical work, since the students already have a secondary technical education.

The main object of practical training should be to acquire experience for the independent inspection of various gages in the capacity of a government inspector, for general inspection work, for the inspection of the establishments of departmental supervision, the licensing of establishments engaged in the manufacture, repair and authorized inspection of measuring equipment, etc.

Specialists coming from the Metrology College and those having technical university education should not be sent to courses for government inspectors. They should only take the necessary examinations for the external diploma of government inspector. Such persons should only be examined in subjects concerned with metrology.

In the increase of technical qualifications great importance should be attached to the work in the 1st class state inspection laboratories and institutes in acquiring knowledge of the new types of inspection.

The organization of seminars on special types of measurements at the institutes, such as those already held at the Sverdlovsk branch of the All-Union Scientific Research Institute of Metrology, would be a very useful measure. These seminars examine scientific research problems in a definite field of measurements and the subjects of further metrological research, the question of the introduction of new regulations, the automation and rationalization of inspections, the problems of application and recommendation of various devices intended for speeding-up and simplifying inspection operations, etc. The exchange of experience between those taking part in the seminar is very useful.

For the heads of SIL, and for persons supervising the application of standards and the compliance of measuring equipment with technical specifications, the Committee should organize seminars for studying the practical problems of organization and operation of laboratories.

Assistance of SIL by the institutes. The question of practical help which can be given by the institutes to the laboratories linked with them, including visits by members of the institutes is a matter of great importance. The experience of the Sverdovsk branch of the All-Union Scientific Research Institute of Metrology, and the Khar'kov State Institute of Measures and Measuring Devices, shows that great advantages can be gained from this cooperation between laboratories.

The time is ripe to revise the relations between the laboratories and the institutes of the Committee. For example, the Novosibirsk State Institute of Measures and Measuring Devices supervises all the laboratories of the Uzbek, Kazakh, Tadzhik, and Turkmenian Union Republics, as well as the laboratories of Siberia and the Far East. Naturally, it is not possible to give effective help to such a large number of laboratories located a considerable distance away from the Institute. The great expansion of the national economy in the Eastern regions of the country calls for a rapid solution of this problem.

In the near future the problems which are connected with general planning, the working out of a definite, realistic, and well-founded plan, progress reports, financing of the work done by the SIL, the working out of a premium system and a basis for the remuneration of government inspectors, etc., must be solved. Socialist competition is also in need of further development.

From the Editorial Board. This article by B. L. Sokolov raises questions which are of great importance to the work of the inspection establishments of the Committee in connection with the adoption of new forms of government inspection of measuring equipment. The Editorial Board invites the readers of this Journal – members of the institutes of the Committee, of the SIL, of the institutions of departmental inspection, and others – to submit their suggestions. This will be of help in the defining of the new forms of work.

LINEAR MEASUREMENTS

THE URT-5 ULTRASONIC RESONANCE THICKNESS GAGE

I. N. Ermolov and M. F. Krakovyak

Thickness measurements on parts that have only one surface accessible are possible with ultrasonic equipment. Thicknesses of 10-20 mm are measured with pulse equipment [1, 2]; smaller thicknesses are measured by resonance methods.

The V4-8R resonance gage is in regular production in the USSR, and a certain number of UZT-4M units (TsNIITMASh system) have been made for experimental purposes [1, 3]. In both instruments the readings are not direct, since the scale readings have to be worked up on special nomograms to get the thickness.

Foreign firms make direct-reading gages [4, 5]. These instruments are inconvenient in that they are large and heavy. Some rather complex adjustments have to be made before readings are taken; the mean thickness has to be estimated, and then appropriate scale for future use is selected.

In 1957 TsNIITMASh produced the URT-5 resonance thickness gage, which can be used without scale-changing or resort to nomograms. The range of thicknesses measured is large, and special probes are provided for use in measurements on tubes of small diameters. Figure 1 shows the circuit.

The tube T_1 is connected in a transition circuit to produce high-frequency oscillations. The inductance L_1 and the two coupling turns L_2 form parts of the oscillatory circuit, as do the screened cable and piezoelectric head P. The frequency may be varied from 3 to 9 Mcs by magnetizing the oxifer-400 core of the coil L_1.

The electromagnet M magnetizes this core; the magnet is fed from the plate of T_2. The control grid of this tube is fed with a sawtooth voltage produced by the circuit C_1R_1. The capacitor C_1 is charged by the secondary of the power transformer Tp1 via the rectifier B_1; it discharges via R_1. The voltage on C_1 is used to perform the frequency modulation, and to produce the horizontal sweep on the oscilloscope by means of the push-pull amplifier built around T_3.

The probe P transforms the electrical oscillations into elastic ones. The frequency modulation ensures that resonance is set up in the part at some instant. The resonance occurs at a frequency

$$f_n = \frac{nv}{2d}, \tag{1}$$

where d is the thickness, v is the speed of ultrasound and n is an integer (the harmonic number).*

The plate current of the oscillator increases when the part resonates. The frequency is modulated at 50 cps, so the increase in current lasts only a short while. The resulting current pulses are passed through a T-type filter, which eliminates the slow change in plate current caused by the frequency modulation, and are amplified by T_4 to work the vertical sweep. The various resonances are seen as distinct peaks, because the x-sweep is synchronized with the frequency modulation.

The value of n corresponding to any given pulse usually is not known in advance, so the thickness can be found from (1) only if the mean thickness is known approximately.

* It is assumed here that the outer and inner surfaces are not coupled to any other body.

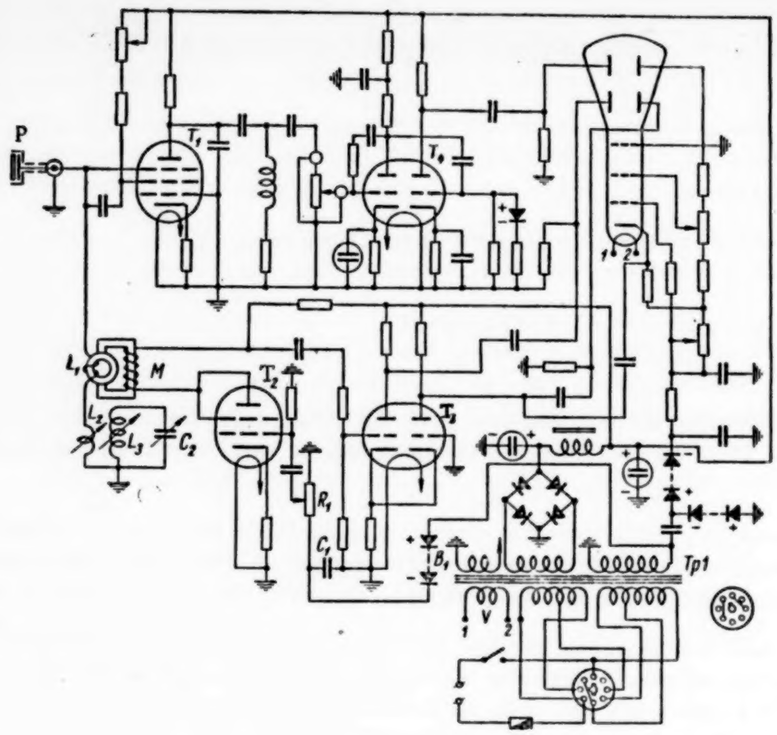

Fig. 1.

It is more convenient to deduce the thickness from

$$d=\frac{(m-n)\ v}{2\ (f_m-f_n)}, \tag{2}$$

which is easy to derive from (1). Here (m-n) is the difference of the harmonic number corresponding to resonances at frequencies f_m and f_n.

The thickness-reading circuit consists of the resonant circuit L_3C_2, which is coupled inductively to the oscillator. When the actual oscillation frequency is the same as the frequency to which this frequency meter is tuned, the oscillatory circuit is damped, and a marker pulse is produced on the screen. The L_3C_2 circuit is tuned by varying C_2; the marker pulse then moves along the x-axis. The measurements are made by bringing the marker pulse into coincidence with the mechanical resonance pulses. The reading α on the capacitor's scale is then uniquely related to the frequency f_n of the mechanical resonance.

The main feature of this direct-reading system is that the law followed by C_2 is linear in the angle of rotation α:

$$f=\frac{k}{\sqrt{L_3}}(\alpha+b), \tag{3}$$

where <u>k</u> is a coefficient of proportionality, L_3 is the inductance, and <u>b</u> is a constant.

We substitute (3) into (2) and get

$$d=\frac{(m-n)\ v\sqrt{L_3}}{2\ k\Delta\alpha}. \tag{4}$$

where $\Delta\alpha$ is the angular motion of the capacitor corresponding to the change from f_m to f_n.

Thus (4) shows that d is uniquely related to $\Delta\alpha$.

In practice a thickness reading is made as follows. The marker pulse is brought into coincidence with some one resonance pulse. The release knob is then pressed to uncouple the scale from the rotating part of the capacitor; a spring device then sets the initial reading (∞ mark). The knob is then released and the capacitor is adjusted to bring the marker pulse onto the next resonance pulse. The scale then reads the thickness in mm.

The pulses become numerous and close together if the part is very thick. In this case measurements are made not on adjacent pulses ($m-n = 1$), but on pulses separated by 1, 2, 3 etc pulses. Then $m-n$ is 2, 3, 4 etc. The scale readings are multiplied by the corresponding factors in order to get the true thickness. The most convenient factors for practical use are 2, 5 and 10.

Sometimes only one pulse is seen on the screen. This means that the thickness is less than 0.7 mm; the peak seen is then that for the fundamental ($n = 1$). The thickness is measured by bringing the marker pulse into coincidence with this pulse; readings are then taken from a special scale calibrated in accordance with the formula

$$d=\frac{nv\sqrt{L_3}}{2\,k\,(a+b)}. \tag{5}$$

This scale may also be used when several pulses are seen. In this case n must be found for some one pulse; the corresponding scale reading is then multiplied approximately.

The scale system of the URT-5 is such that materials which differ in their speeds of propagation may be used. Formulas (4) and (5) show that speed changes can be allowed for by changing the inductances appropriately. In practice this adjustment is made on a sample whose thickness is known. Then L_3 is adjusted by means of a variometer made up from two cylindrical coils.

The URT-5 covers a much greater range of thickness than the V4-8R and UZT-4M do. The reading facilities enable one to make direct measurements on a single pulse, or on two adjacent pulses, for parts whose thicknesses range from 0.36 to 10 mm. The range can be extended to 40-50 mm or more by using appropriate scale factors.

The errors in the results derive mainly from nonlinearity in the capacitor and from inexact coincidence between the marker and resonance pulses, The errors amount to $\pm 2\%$.

At small thicknesses there are other errors caused by the broadness of the resonance peak, which may be displaced along the frequency axis. The cause is that the probe is damped by the part [6], which causes the frequency to shift to a frequency higher than (1) predicts.

The pressure on the surface is rather unsteady, so no allowance can be made for this effect. The resulting error δ is defined roughly by

$$\delta=\pm\left(2+\frac{1}{d}\right)\%. \tag{6}$$

The work on the URT-5 included a study of how to reduce the minimum usable radius of curvature for cylindrical parts (especially tubes). The problem is a difficult one, because the probe is in contact with the surface along a generating line (Fig. 2a). The ultrasound can enter the part only if a thin layer of oil comes between the probe and the part. The transmitted intensity falls rapidly as the thickness of this layer increases. Some small region near the line of contact is the only region to interact with the probe. The smaller the diameter the smaller this region. Hence the signals given by tubes of small diameter are small and may be comparable with the noise level. We decided to try to reduce the noise level of the oscillator and to modify the probe in such a way as to increase the size of the interaction region.

We found that the core of coil L_1 was the main source of noise. This coil is used to produce the frequency modulation. The material must be of high initial permeability and must at the same time give the circuit a high Q, since the sensitivity is proportional to Q^2.

Materials of oxifer type satisfy these requirements. Their main disadvantage is that Q falls sharply at certain frequencies. The result is to produce false pulses; the effect occurs with other similar materials.

The best core material for L_1 was found to be oxifer-400, which gives the best signal-to-noise ratio in the range from 2 to 9 Mcs.

We also redesigned the probe for use with small-diameter tubes. It is suggested [7, 8] that the piezoelectric plate should have a cylindrical depression (Fig. 2b), or should be made up from a curved plate (Fig. 2c). We found that the first design was of poor sensitivity, and that the curved plates were very fragile and were unsuitable for use in factory conditions.

We found it best to use a two-plate probe (Fig. 2d). The two plates are set at an angle to one another. Both plates touch the tube. The effective volume is thereby doubled, and with it the sensitivity.

We made φ 165°. The two lines of contact were then close together. At diameters D = 20 mm the arc AB is 2.6 mm long. The wall thickness usually varies little within such a distance, so the increased area of contact does not involve an increase in the error of the measurement even with very uneven tubes.

This probe is not suitable for use with flat or slightly curved parts. The complete kit therefore includes normal flat probes, which should be used for two parts whose radii exceed 10-15 mm.

The piezoelectric plate is the main component of the probe. The probe must be designed properly in order to ensure that it works well. The thickness of the plate should be such that the fundamental frequency lies above the working range of the gage. This requirement may be put as

$$s < \frac{v_p}{2 f_{max}}, \tag{7}$$

where $\underline{s}$ is the thickness in mm; v_p is the speed of sound in the plate (in mm/μ sec), and f_{max} is the maximum frequency of the oscillator in Mcs.

The working frequency extends up to 9 Mcs, so the plate is thin. Normally the plates are made from X-cut quartz, for which the speed is 5.76 mm/μsec. Then (7) shows that the thickness is about 0.3 mm. Such plates inevitably get broken frequently in production use.

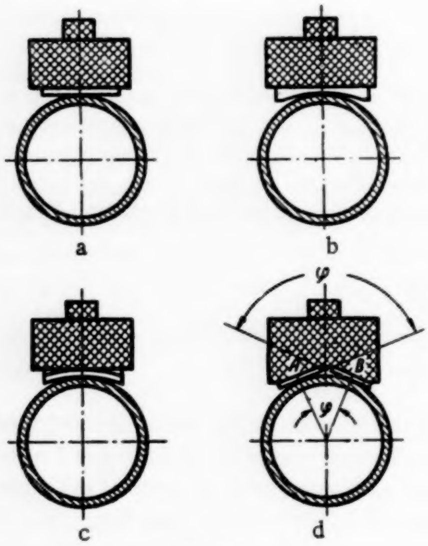

Fig. 2.

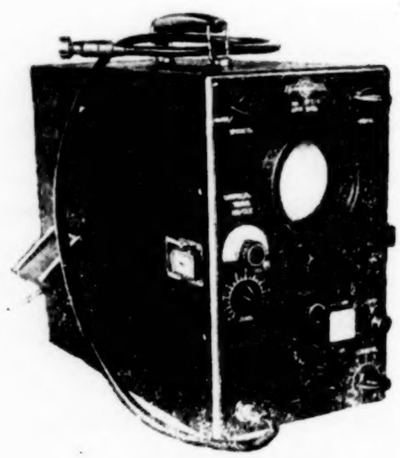

Fig. 3.

Materials having higher values for the speed of ultrasound are of interest here. We have tested one such material, namely tourmaline.* This substance is mechanically very suitable and gives a high Q, its piezoelectric modulus is nearly the same as quartz's, and its dielectric constant is 1.7 times larger than quartz's. The speed of ultrasound in tourmaline is 7.3 mm/μ sec. Tourmaline plates can be 1.25 times thicker than quartz ones.

*A. P. Sviridov, of TaNILKS, suggested that we should use tourmaline and gave us the plates used in our tests.

We found that probes fitted with tourmaline plates gave good results. The sensitivity was 1.5-2 times that given by quartz; the tourmaline was highly wear-resistant. None of the tourmaline plates gave false pulses, whereas more than 50% of our quartz ones were scrapped because they gave strong false pulses within the working frequency range.

The above improvements to the probe and circuit enabled us to use much smaller tubes. The V4-8R and UZT-4M cannot be used with tubes whose diameters are less than 30 mm, whereas the URT-5 can be used with tubes of diameter 10 mm or less.

Figure 3 shows the URT-5. The chassis is in two parts at different levels; the metal case makes the instrument conveniently portable. The recessed pocket holds the cables and probes. The dimensions are 220 × 360 × 425 mm; the weight is 13 kg. The unit is fed from the 110/127/220 v a.c. line; the power drain is 40 w.

A first model of the URT-5 made at TsNIITMASh has passed laboratory tests and has been sent for use at one of the factories.

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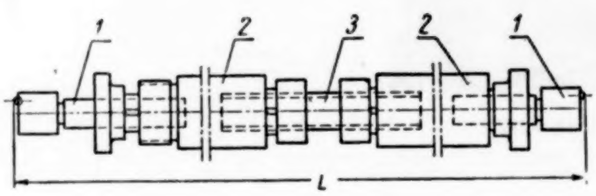
A UNIVERSAL TEST-PIECE FOR USE WITH MICROMETERS OF THROAT OVER 100 mm

A. N. Dolgushev

We have made a universal test-piece for testing for parallelism in the faces of micrometers whose upper limits lie above 100 mm; this test-piece consists of the tips 1 containing press-fitted balls, of the spacers 2 with grips (which may be made up from scrapped micrometers), and of the threaded extension piece 3.



The test-piece is assembled as above, and is checked to ensure that the balls lie exactly on the axis. Special clamps are used to fix the test-piece to the micrometer.

The tips are prevented from turning and thereby displacing the balls from the axis by fastening the clamping device.

The micrometer is then tested in accordance with instruction 135-57; a change in length of the test-piece corresponding to 1/4 clockwise turn of the micrometer screw is produced by turning the extension piece, for which purpose one of the clamping nuts on the holding parts is released and then retightened.

This type of test-piece can be used to check micrometers of any range; only the extension piece need be changed. The length of the test-piece need not be checked.

This test-piece obviates the need for four special test-pieces differing from one another by steps of 0.12 mm.

DEVICE FOR THE COMPLETE INSPECTION OF I-C ENGINE CAMSHAFTS

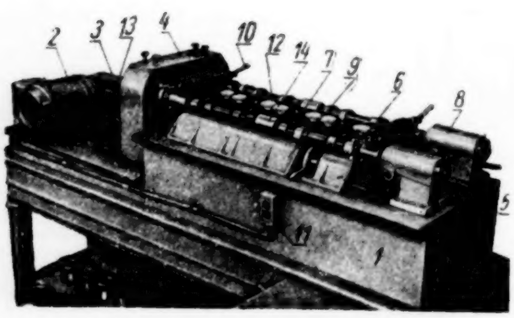
N. M. Borzak and A. M. Chernyak

The device illustrated in the figure was developed and used for the efficient and complete workshop inspection of tractor engine camshafts. The inspection is effected by comparing the positions of points of the profile of the cams of the shaft being inspected with the positions of corresponding points of a precision-machined and checked master camshaft, which remains clamped in the device.

The device incorporates the following main parts; bed 1 which carries all the component parts of the device; the motor 2 which drives the master shaft and the shaft being inspected; the reduction gear 3; the casing of the transmission 4 which connects the reduction gear and both camshafts; four roller blocks 5 which support the journals of the camshafts; slides 6 with eight dial indicators and eight pairs of movable and stationary disks 7; two tailstocks 8 with self-aligning floating centers (in a vertical plane), designed for receiving any axial loads; the mechanism 9 for the withdrawal of slides during loading or unloading of the shafts; roller clamps 10 for pressing the shaft against the support blocks; the push-button control unit 11; the master shaft 12; and the pins 13 arranged inside the spindles of the transmission gear and intended for fixing and adjusting the master camshaft and the camshaft being inspected.

The reduction gear and the gears of the transmission mechanism give the camshaft a speed of 5 rpm.

The stationary disks which are pressed against the profiles of the cams of the master shaft move the slides with sleeves. Since the movable disks are pressed against the profile of the cams of the camshaft 14 being checked, their deviations from the correct profile of mutual position are transmitted to the indicator whose readings show the actual size of deviations.



Described inspection device.

The inspection of one shaft lasts no longer than 5 minutes.

SUMMARY

Now that this device has been made at the Central Tools Laboratory of the plant, only every 500th shaft is inspected instead of every 50th shaft as previously. Only 2-3 shafts are inspected in order to detect any possible defects in the manufacturing process of the camshafts, per shift.

AN INTERNAL INDICATOR GAGE FOR RINGS AND SLEEVES

V. V. Nikiforov

Good results with respect to accuracy and productivity were obtained in measuring the internal dimension of a large number of components by using the internal gage suggested by the author; the design is shown in the figure.

The column 7 is screwed to the bed plate 1; the hardened and ground sleeve 9, the external diameter of which slides to fit in the hole being inspected, is screwed to the column by means of screw 14.

The bracket 5 holding the indicator 6 is arranged with the clamp 15 inside the sleeve. The bracket is joined to the sleeve by means of four screws 8 and 10. The movable lever 4 connected with the indicator bracket by means of the elastic member 12 (made in the shape of a leaf spring) by screws 13, is also placed inside the sleeve. The lever 4 is held away from the bracket 5 by means of the leaf spring 17.

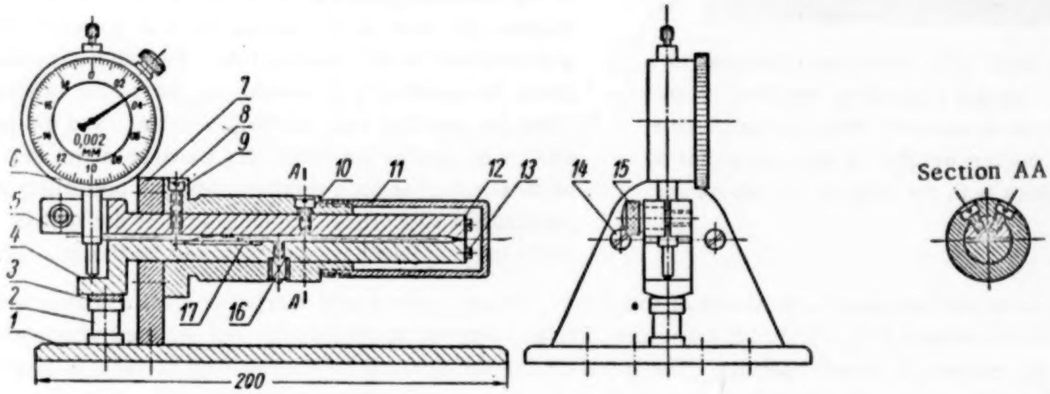
The pin 16 with a ball on its end is firmly screwed to the middle of the lever. The distance from the indicator plunger to the elastic member 12 is exactly twice more than the distance from the axis of the pin 16 to the same member. This arrangement doubles the accuracy of the indicator readings.

The stop 2 with a rubber damper 3 protects the indicator plunger against shock when the ball of the measuring pin leaves the surface being measured.

In order to protect the bracket 5 and the lever 4 against occasional impacts the cap 11 is screwed onto the sleeve.

The indicator is set to zero against a master ring. Gage blocks with slide attachments can also be used for this purpose.

The device was used in measuring the differences between the internal diameters of sleeves with a nominal diameter of 35 mm, and produced good results.



THE ADAPTATION OF AN OPTICOMECHANICAL PROFILOGRAPH FOR THE MEASUREMENT OF THE WAVINESS OF SURFACES

M. M. Palei

An opticomechanical profilograph with specially designed supporting members shaped as a section of a cylindrical surface or a prism, for the inspection of cylindrical surfaces, or with a flat support for the inspection of flat surfaces was employed in measuring the waviness of a surface. The supporting member for measuring a longitudinal waviness is designed as a sector (Fig. 1) whose length extends over not less than two wave crests. An opening is left in the middle of the sector for the stylus of the device. The sector is connected with the measuring head of the device by means of a double pivot which ensures the self-alignment of the support with respect to the surface being inspected.

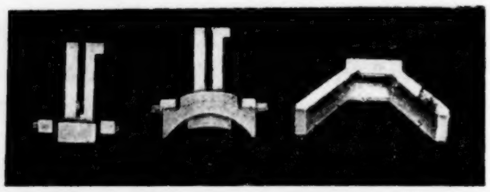


Fig. 1. Supporting members for measuring the longitudinal waviness.

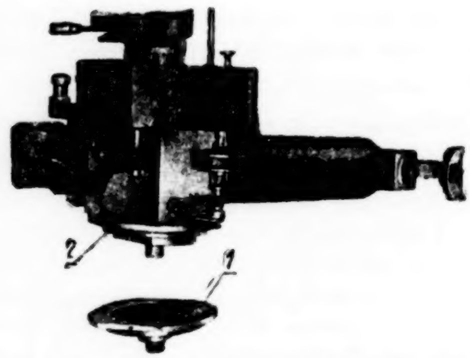


Fig. 2. Connection between the slide and the carriage. 1) Connecting member with centers; 2) connecting member with holes for centers.

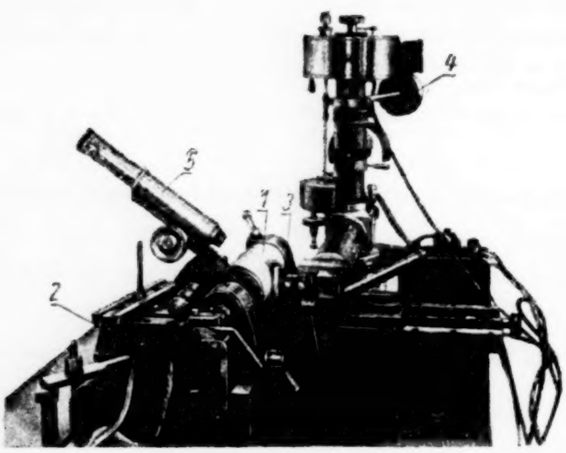


Fig. 3. Profilograph with attachment for rotating a piston pin. 1) Special supporting member; 2) motor for rotating the work mounted between the centers; 3) centers; 4) counter-weight; 5) microscope for setting the workpiece with the help of an indentation.

The incorrect centering of the component and the errors in the height adjustment of the stylus have a considerable effect upon the accuracy of the recorded diagram; for this reason provisions were made in designing the device which ensure the elimination of the influence of these factors. These measures included the introduction of an additional flexible connection at the centers of the slide (Fig. 2), which achieved the self-adjustment of the measuring slide in a vertical plane. In order to balance the mass of the measuring slide a counterweight was attached to the vertical tube. For the horizontal plane the possibility of turning the measuring carriage about the vertical tube has been retained, and the possibility of turning the measuring carriage about the vertical tube has been retained, and the possibility of pressing the supporting members against the surface being investigated has been provided by fixing a spring.

For measuring the longitudinal waviness of small components, centers with a drive producing a slow rotation of the component were used (Fig. 3). For the rotation of large components special devices are used which rotate them between the centers or in ball bearings. The speed of rotation depends on the required horizontal magnification of the diagram and is calculated from the speed of the photographic film and the number of revolutions, with the diameter of the component taken into account.

For measuring the waviness of a cylindrical surface a flat support shaped as a prism, or a section of a cylinder, can be used.

The available model of the Ammon profilograph has a horizontal magnification of 10×; 30×; and 50×. For taking the diagrams of flat surfaces, or of a cylinder when a smaller horizontal magnification is needed, an additional reduction gear with a transmission ratio of 10 : 1 is used in the drive of the shaft rotating the film reel. With this reduction gear the diagrams can be recorded, without a horizontal magnification, from a large-pitch waviness, and with a 3×-5× magnification from a small-pitch waviness.

In order to eliminate the effect of roughness during the measurement of waviness a diamond stylus with a small tip radius can be replaced by a feeler with a spherical tip. The radius R of the feeler is selected so that it can be accommodated by the space between two waves, and so that it is not smaller in size than a sag between two microirregularities. For finding R the following expression is used:

$$\frac{l^2}{8h} < R < \frac{L^2}{H_{в}\, 2\pi^2},$$

where l is the distance between two microirregularities; h is the height of a microirregularity; L is the distance between the crests of a wave; and H_W is the height of a wave.

The profilograph modified as described above can be used for measuring the wear of a wavy surface by comparing the diagrams taken before and after a test run. For the easy identification of a certain area on the components before and after the operation, special marks can be used. An identation produced by the diamond tip of a hardness tester proved a useful mark. To apply it,a microscope (Fig. 3) is mounted on the plate which carries the profilograph. Before taking the waviness diagram an impression of the tip produced on the component is set against the cross in the eyepiece of the tool microscope. When the waviness diagram is again taken after the test run, the component is mounted in centers, with the help of the microscope, in such a manner that the mark coincides with the cross in the eyepiece. This arrangement makes certain that the diagram is taken at the original point.

MECHANICAL MEASUREMENTS

THE EFFECT OF THE KNIFE-EDGE RADII OF THE BALANCE BEAM UPON THE SENSITIVITY OF BALANCES

A. I. Suvorov

Assuming that the knife-edges and their supports are perfectly elastic and that the knife-edges are mathematical straight lines, the sensitivity equation of the balance beam can be approximately expressed by the familiar expression:

$$\operatorname{tg}\alpha_1 = \frac{qa}{RS + Qm}. \tag{1}$$

where α_1 is the angle of incline of the beam under a small weight added to one of its arms; q is the weight applied to one of the arms of the beam; a is the length of a beam arm; R is the weight of the beam; S is the distance between the point of support and the center of gravity of the beam; Q is the weight of the pans, hangers, and weights; and m is the distance from the point of support and the line passing through the apexes of the load-supporting knife-edges.

If it is assumed that the knife-edges are not mathematical straight lines which have only one dimension, length, but have a kind of cylindrical surface with very small radius, then during the oscillations accompanying the weighing process which changes the position of the beam, the points of contact between the knife-edges and their supports will not remain the same but will change their position with respect to the supports in accordance with the respective angle of incline of the beam.

In the horizontal position of the beam (Fig. 1) the contacts between the knife-edges and their supports will take place at points C, O, and C' with the arms of the beam remaining equal.

When a small weight q is added to one of the arms (Fig. 2) then the beam tilts through an angle α.

Owing to the rolling of the knife-edges on their supports the points of contact change and occupy the positions b and b'; at the same time the left-hand (rising) arm of the beam lengthens and the right-hand arm shortens.

After denoting by r, r_1, and r_2 the radii of the knife-edges and assuming that they are equal, it is easy to find that the lengthening of the left arm and the shortening of the right arm are equal:

$$\Delta a = 2r \sin \alpha.$$

The difference between the arms of the beam is:

$$y = 4r \sin \alpha.$$

In solving the sensitivity equation of balances this quantity cannot be ignored and the equation takes a shape somewhat different from (1).

In order to simplify the equation of sensitivity which takes into account the radii of the knife-edge tips we assume that there is no difference between the lengths of the arms of the beam when it is in a horizontal position, that the center of gravity is below the support and that the distance between the center of gravity and the

support is S; the line connecting the tips of the knife-edges is also below the supports, at a distance m from them; the edges are cylindrical, with r being the radius of the main knife-edge and r_1 and r_2 the radii of the knife-edges directly carrying the loads; we denote the length of one arm of the beam by a and the weight of the beam by R.

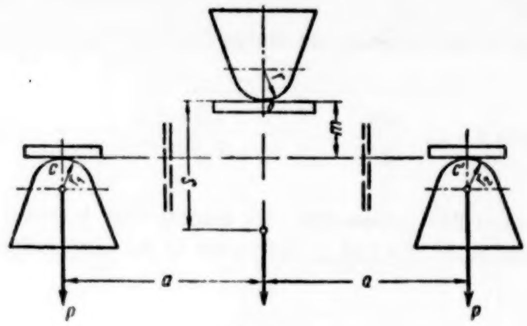


Fig. 1.

Let us now consider the equilibrium conditions of the beam when a small weight q is added to the weight P previously placed onto the right-hand pan, causing a deflection from the horizontal position by an angle α.

Since the beam inclined under the load q can be in equilibrium only when the static moment of the forces acting upon both sides of the main support are equal, the following equilibrium equation can be formulated:

$$P[r_1\sin\alpha + a\cos\alpha + (m+r)\sin\alpha] + R(r+S)\sin\alpha = \\ = (P+q)[a\cos\alpha - (m+r)\sin\alpha - r_2\sin\alpha].$$

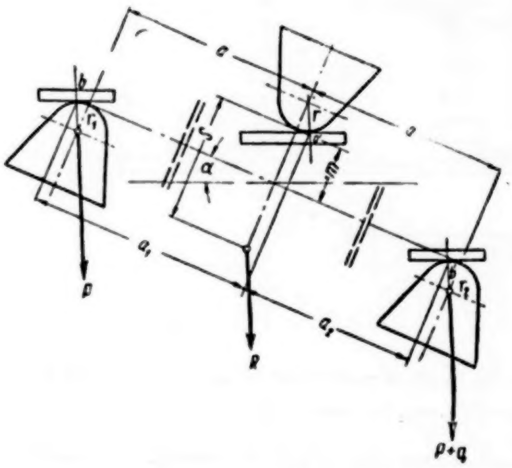


Fig. 2.

After making necessary algebraic calculations and dividing both sides of the equation by $\cos\alpha$, we obtain the following equation:

$$\mathrm{tg}\,\alpha_2(2Pm+2Pr+Pr_1+Pr_2+RS+Rr+qm+qr+ \\ +qr_2)=qa.$$

When the load q is added, the tangent of the angle of incline represents the sensitivity of the balances, which for the sake of easy handling can be expressed as

$$\mathrm{tg}\,\alpha_2 = \frac{qa}{(2P+q)\,m+RS+(2P+R+q)r+(P+q)r_2+Pr_1}.$$

This equation shows that the radius of the main knife-edge which, during the operation carries the highest load and, consequently, suffers greater wear than the other edges, has the greatest effect upon the sensitivity of balances.

The effect of static moments of forces qm, qr, and qr_2 which are contained in the denominator of the right-hand part of the equation are relatively small compared with the other quantities contained in the equation, and have only a small effect upon the sensitivity, so that they can be ignored. Actually, the radii of the main knife-edge and of those which carry the loads, differ so little from one another that we can assume that $r = r_1 = r_2$. Then the equation of sensitivity can be written as

$$\mathrm{tg}\,\alpha_2 = \frac{qa}{2Pm+RS+(4P+R)r}.$$

In the equation obtained the quantity 2P is the weight of the load with pans and hangers which was earlier denoted by Q. In this case the equation takes the following shape:

$$\mathrm{tg}\,\alpha_2 = \frac{qa}{Qm+RS+(2Q+R)r}. \tag{2}$$

The equation of the sensitivityof balances thus obtained differs from (1) by the term $(2Q + R)r$ in the denominator.

In order to assess the effect of this term upon the sensitivity of the balances we divide (2) into (1):

$$\frac{tg\alpha_2}{tg\alpha_1}=\frac{qa(Qm+RS)}{qa[Qm+RS+(2Q+R)r]}=\frac{Qm+RS}{Qm+RS+(2Q+R)r}, \text{ with } S = m \quad \frac{tg\alpha_2}{tg\alpha_1}=\frac{(Q+R)S}{(Q+R)S+(2Q+R)r}. \quad (3)$$

Let us consider a numerical example for analytical balances of 200 g capacity. We assume that the total load together with pans and hangers is Q = 500 g, the weight of the beam R = 128 g; the radius of the knife-edges r = 0.007 mm; and the distance S = m = 0.04 mm.

By substituting these quantities into (3) we obtain:

$$\frac{tg\alpha_2}{tg\alpha_1}=\frac{(500+128)\cdot 0.04}{(500+128)\cdot 0.04+(2\cdot 500+128)\cdot 0.007}=0.76,$$

i.e., $\tan\alpha_2 = 0.76 \tan\alpha_1$.

For balances without the load, and pans weighing 100 g, we obtain:

$$\frac{tg\alpha_2}{tg\alpha_1}=\frac{(100+128)\cdot 0,04}{(100+128)\cdot 0.04+(2\cdot 100+128)\cdot 0.007}=0.8,$$

i.e., $\tan\alpha_2 = 0.8 \tan\alpha_1$.

The results of these calculations show that when the effect of the radii of curvature of the knife-edges is ignored in determining the sensitivity of the balances, an error of 20-25% can be produced.

Apart from their effect upon the sensitivity, the radii of the knife-edges also affect the stability of readings and the accuracy of balances; if it is taken into account that the oscillation process of balances is affected by a number of further factors (effect of the frictional force in the kinematic couple knife-edge-support, elastic hysteresis, the inertia forces produced by the movements of the object being weighed and resulting in the rocking of the pans with weights, etc.) then it becomes clear that the study of balances is far from being completed and should be steadily continued in both the theoretical and the experimental directions.

INVESTIGATION OF THE INTERMEDIATE MECHANISMS OF DIAL SCALES WITH ADDITIONAL WEIGHTS

A. L. Shneiderman

During testing many types of Russian-made dial scales with built-in additional weights, errors were detected which increase on entering each subsequent stage of the range.

The systematic investigations of such scales showed that the cause of these errors is the intermediate mechanism.

The schematic diagram of the most widely used type of intermediate mechanism is shown in Fig. 1.

In designing intermediate mechanisms the linkage is usually based on the principle normally used in scales: in shaping the main lever (located below the dial) it was attempted to adhere to the "line of knife-edges" and

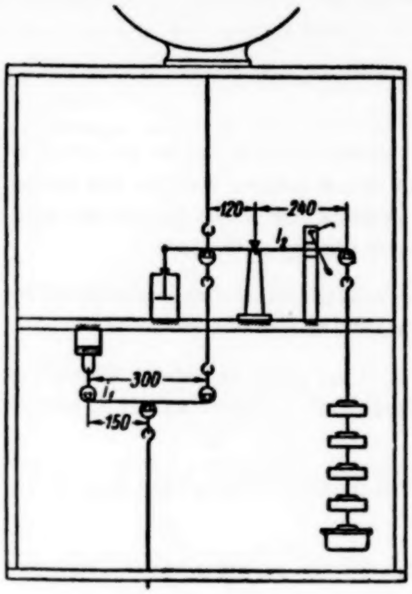


Fig. 1.

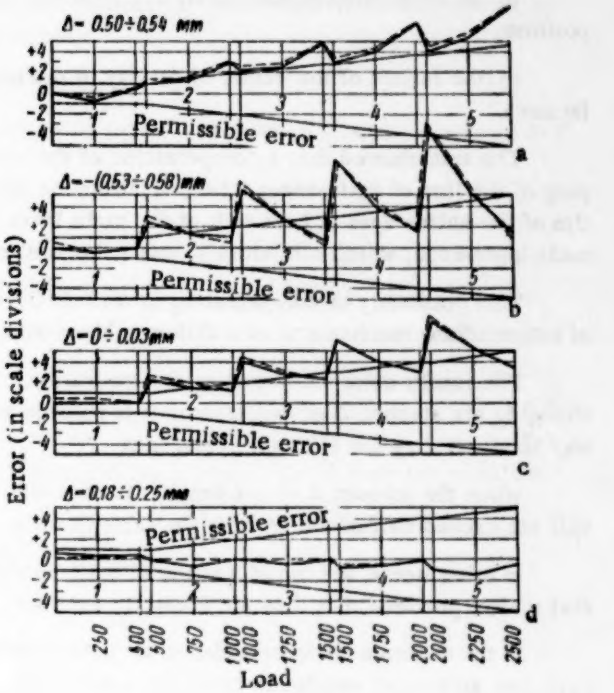


Fig. 2.

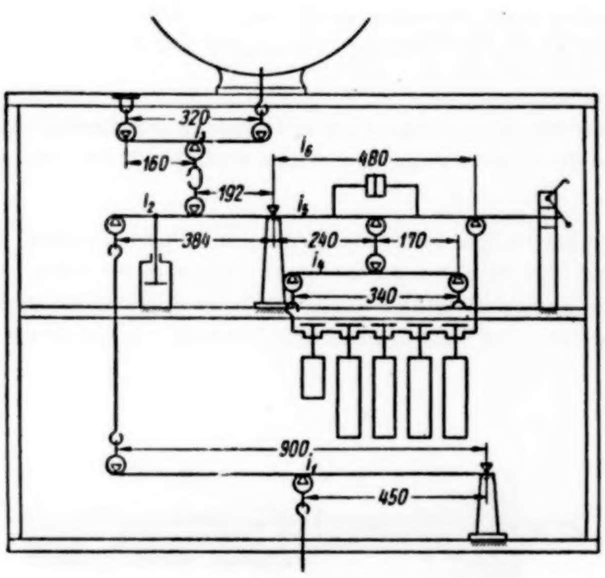


Fig. 3.

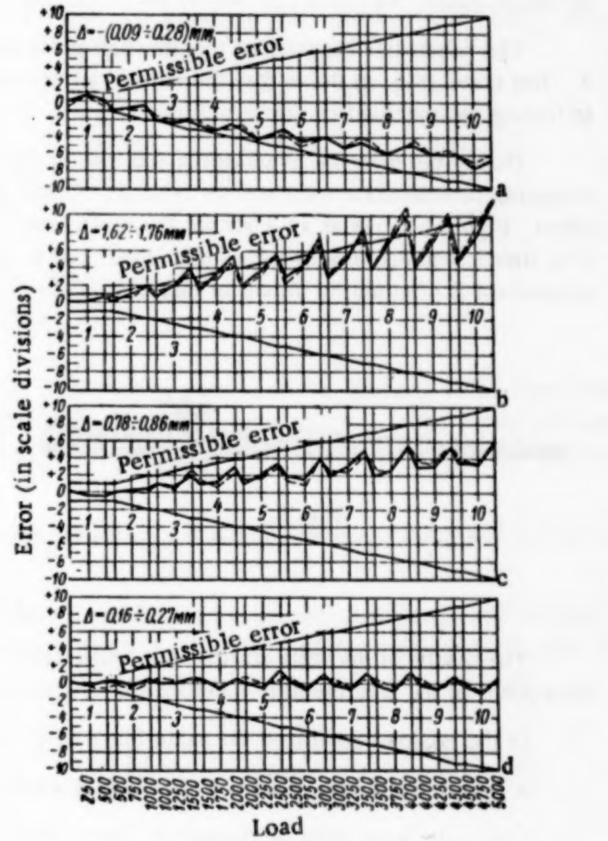


Fig. 4.

achieve a coincidence between the center of gravity of the lever and its axis of rotation, in order to eliminate the effect of the inclination of the lever upon the indications of the scale.

An examination of the equilibrium conditions of a lever showed that the errors of the above type may be caused by:

a) the flexure of the lever, which results in a displacement of the knife-edges on its ends with respect

to the main supporting knife edge, and the lowering of the center of gravity of the lever;

b) an inclination of the connecting links due to the inclination of the lever from its original horizontal position;

c) the failure of the center of gravity of the lever to coincide with the axis of rotation (due to faulty manufacture).

The tests showed that a compensation of the above mentioned sources of error can be achieved by an "overlapping of the line of knife-edges," i.e., by arranging the knife-edges in such a manner that the line connecting the tips of the knife-edges at both ends of the main lever in its no-load position runs above the contact line of the main knife-edge, which substantially raises the position of the center of gravity of the lever.

This possibility of compensating errors introduced by the intermediate mechanism was tried on several models of intermediate mechanisms with different kinematic layouts, designs, and ranges of measurement.

The results obtained in testing the mechanism illustrated in Fig. 1 are given in Fig. 2. This shows that by changing the amount Δ of overlapping it is possible to affect considerably the absolute values of errors and the way in which they are affected by the load.

When the amount Δ of overlapping is correctly selected then the maximum indication error of the scales will not exceed half of the permissible value (0.05%).

In other words, the use of additional built-in weights makes possible the lowering of the indication error of dial scales, provided that they are correctly adjusted.

In the example being considered the indication error of scales with a maximum capacity of 2500 kg, which have four additional weights to cover the entire range, does not exceed 1.5 times the value of the smallest dial division (500 g).

In addition to the testing of an intermediate mechanism made according to the diagram shown in Fig. 1, tests were also carried out with an intermediate mechanism with a horizontal platform for weights, which was designed by the Scientific Research Institute of the Scales Industry.

The schematic diagram of this mechanism is shown in Fig. 3, and the results of its testing are given in Fig. 4. The curve (Fig. 4) shows that the correct adjustment of the scales can produce results similar to those obtained in testing the mechanism shown in Fig. 1.

During the tests the overlapping was altered by using knife-edges with working lines at different heights. In designing intermediate mechanisms facilities should be provided for altering the mutual position of the knife-edges. Figure 5 shows as an example the main lever of the Swedish "Statmos" scale which incorporates an adjustable link 1, and Fig. 6 shows the main lever used in the scales of the West German firm "Bizerba," in which the adjustment is effected by means of inserts 1.

Fig. 5.

Fig. 6.

SUMMARY

The results of our tests entitle us to make some practical suggestions regarding the design, manufacture, and adjustment of the intermediate mechanisms of dial scales with built-in additional weights:

In the no-load condition the main lever must be in a labile equilibrium;

A regulating device must permit a height adjustment of the center of gravity;

The main lever must be thoroughly tested in its assembled position (until definite data on the mutual position of the working lines of knife-edges are obtained);

The intermediate mechanism must be tested by plotting the curves for the error-load relation.

The adjustment must be performed by means of special adjustment elements (individual adjustment by regulating the mass of the weights being added is not permissible);

The mass of each additional weight must be limited to 5-6 kg.

The maximum angle of inclination of the main lever from its horizontal position should not exceed 5-6°.

SIMPLIFIED CALCULATIONS IN CHECKING ANALYTICAL BALANCES

E. E. Zaslavskii

During the checking of analytical balances the equilibrium position L is calculated from the equation:

$$L=\frac{l_1+2l_2+l_3}{4},$$

where l_1, l_2, and l_3 are the amplitudes of the vibrating pointer.

The numerator of this expression is readily calculated mentally; however, during the division the numbers are made round the nearest ten, with resulting errors.

In order to simplify the calculations we use the following order: instead of the value L we calculate the four times higher value $L_i = l_1 + 2l_2 + l_3$ which is four times higher; the suffix i denotes the number of the operation during the checking, according to the Instruction 57-56. In this case the equations for calculating the value of a division and the difference in the lengths of the arms take the shape:

$$S_{0.1}=\frac{4r}{L_4-L_3}; \qquad S_{lim}=\frac{4r}{L_8-L_7};$$

$$Y_{0.1}=\frac{L_2+L_3-L_1-L_5}{L_4-L_3}\cdot\frac{r}{2}$$

and

$$Y_{lim}=\frac{L_6+L_7-L_5-L_9}{L_8-L_7},$$

where $S_{0.1}$ and S_{lim} are the values of a division for 0.1 times the limiting value and the limiting value respectively; r is the mass of the small weight which is added in determining the value of a division; $Y_{0.1}$ is the factor indicating the difference in the lengths of the arms at 0.1 of the limiting load; and Y_{lim} is the factor indicating the difference in the length of the arms at the limiting load.

If the weight r is 2 mg then the factor r/2 in the expression for $Y_{0.1}$ and Y_{lim} becomes unity and the equations become even more simple.

In addition to a considerable acceleration of the calculations and the elimination of the causes of calculation errors the suggested order improves the accuracy of results and does away with the need for making the figures round during intermediate calculations.

INDRIK'S WEIGHT-AND-PISTON BAROMETER*

P. V. Indrik

Standardized mercury barometers are used to obtain exact values of the barometric pressure. These instruments are difficult to use because many corrections have to be made, and because they cannot be made portable.

The high accuracy given by weight-measuring instruments can be put to good use in producing standard pressures; mercury devices can be eliminated. Work on piston gages has resulted in the gage described here, which was made at the All-Union Metrology Research Institute (VNIIM).

Figure 1 shows the system used. The main part is the cylinder 1, which encloses the piston 2. The piston and shaft 3 are made hollow to reduce the weight. The lower part of the piston carries the load 4, which balances the atmospheric pressure when the chamber is evacuated.

The apparatus is held in a special framework (not shown) by means of the threaded end and nut 5. The framework is fitted with levelling screws for setting the cylinder vertical, for which purpose the plumb bob 6 is used.

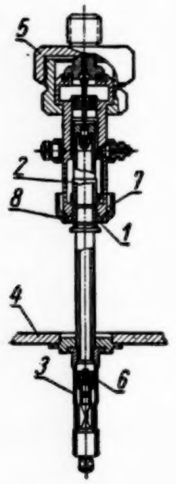


Fig. 1.

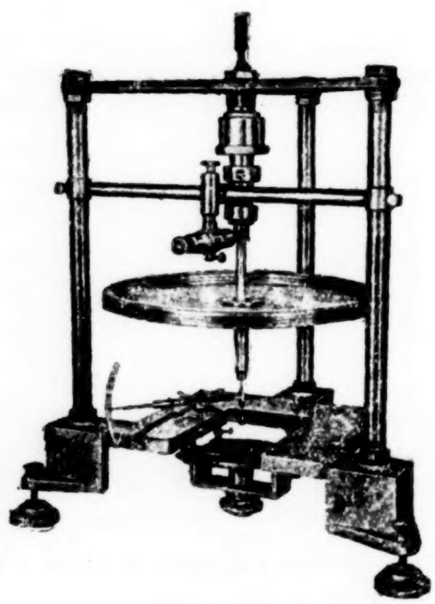


Fig. 2.

The ring-shaped weights have high moments of inertia and ensure that the piston rotates for a reasonable time.

The piston has an area of 5 cm^2, which makes for high accuracy. The working fluid is dibutyl phthalate, which has a vapor pressure of about 10^{-5} mm Hg. The feed channels 7 allow the liquid to enter the working gap from the cup 8.

In the new model (Fig. 2) small weights do not have to be added by hand because a tangential loading (spring balance) system is used; it is possible to measure load changes of 0.5-1.0 g accurate to 20-25 mg.

*Author's certificate No. 63541 of July 2, 1939 for a piston barometer.

The new model has been compared with a standard mercury barometer and with a secondary pressure standard; the root-mean-square error is about 5-6 μ Hg.

SUMMARY

The accuracy is equal to that of the best mercury barometers. The instrument has substantial advantages over mercury-based ones. The accuracy of the latter depends mainly on how accurately the temperature correaction (about 140 μ Hg per °C) is made. The correction is smaller by a factor 18 for the piston barometer. The care needed in controlling the temperature is thus much less, and the results are more reliable.

A SUBSTANDARD WEIGHT-AND-SPRING PISTON BAROMETER

K. I. Khansuvarov

The need to make a substandard class I barometer arose from lack of means of comparing the standard mercury barometer at the All-Union Metrology Research Institute (VNIIM) with the fixed mercury barometers of the Meteorological Service of the USSR. Highly accurate barometers are also needed in some branches of metrology (in absolute length measurements by interference methods; in standard temperature measurements).

The most accurate barometers at present available employ two principles, namely

1) balancing the atmospheric pressure against a column of liquid (mercury), and

2) balancing the atmospheric pressure against the forces given by springs of various types.

Mercury barometers are at present the most accurate. The standard barometer at the Institute can be read to about 0.005 mm Hg, while the automatic digital mercury barometer (National Bureau of Standards, USA) reads directly to a thousandth of an inch (about 0.025 mm Hg). The best spring barometers are also very accurate. The spring microbarometer (Askania-Werke, W. Germany) has a sensitive element in the form of a hollow multi-turn helical spring, and can be read to 0.01 mm Hg. The microbarograph made by the same firm reads the atmospheric pressure to 0.03 mm Hg.

A class I substandard barometer must be highly accurate (0.02 mm Hg) and portable. This latter requirement makes a mercury barometer unsuitable, since an accurate mercury barometer is cumbrous and needs very careful adjustment after it has been moved. In 1955-56 V. N. Gramenitskii and the author proposed one possible solution to this problem in the form of a mercury-piston barometer with a balanced piston [1]; this satisfied the main requirements for a class I substandard barometer. A small batch of such barometers was attested at VNIIM for various organizations.

The presence of mercury and the complexity of the adjustments were disadvantages, so work on a better design free from mercury was continued.

This paper gives some results from this work.

Principles and Theory. The simplest system for a barometer with an unsealed piston is that of the floating piston. This principle was first used in Indrik's vacuum gage [2]. The pressure so measured is defined by the weight and effective area of the piston.

But if the atmospheric pressure, which may vary widely, is to be measured, it is inconvenient to use weights, because very small fractional weights have to be used if the measurements are to be accurate, and so each measurement takes a long time. The atmospheric pressure may change during these tedious operations. The measurements are also made difficult by the inertia of the piston in conjunction with the perturbing forces involved in changing the weights.

Therefore the system must be modified to include a means of changing the weights smoothly without handling fractional weights. To this end the authors have proposed a spring-and-piston barometer [3].

In this system the barometric pressure is balanced in two ways; the weight of the piston balances out the major part of the pressure, and any extra force is provided by a spring.

There are two distinct ways of realizing this principle, which differ in the purpose of the two spiral springs fixed to the axle of the spring mechanism.

In the first system an exact balance is produced. The piston is kept at a fixed position by adjusting the force exerted by one of the springs, which operates in torsion. The force is given by

$$N = k_1\varphi_1, \tag{1}$$

where k_1 is the rigidity of the spiral spring and φ_1 is the angle of torsion.

The second spring is intended only to reduce the inertia.

In the second system the compensation is not complete. The force exerted by one of the springs can be adjusted in steps. Within the range of any one step any change in atmospheric pressure is taken up by the changed force exerted as a result of a slight movement of the piston. The force is then given by

$$N = k_1\varphi_1 + k_2\varphi_2. \tag{2}$$

where k_2 is the total rigidity of the two springs, φ_2 is the torsion angle corresponding to the displacement of the piston, and k_1 and φ_1 are as in (1).

The second system is better than the first if a direct-reading barometer is needed, since the system comes to balance without any action on the part of the observer. This simplifies the process of taking a reading and reduces the effects of subjective factors.

The first system is better for use in a barograph, because it is easier in this way to make the instrument automatic, as is necessary if the barometric pressure is to be recorded accurately.

The equation for equilibrium is given by the condition that the sum of the forces acting on the piston is zero:

$$G - N - (B - p)F = 0. \tag{3}$$

where G is the weight of the piston (in air), N is the force exerted by the spring mechanism, B is the barometric pressure, p is the pressure over the top face of the piston, and F is the effective area of the piston.

Then the atmospheric pressure is given by

$$B = \frac{G - N}{F} + p. \tag{4}$$

Thus the pressure can be measured in terms of the force exerted by the springs within the range available in that force; the weight of the piston can be kept constant, which facilitates measurements greatly.

The range available in the spring mechanism and the pressure allowed above the piston determine the error in the result. Subject to certain assumptions, the relative error of a reading is indicated by (4) as

$$\delta_B = \sqrt{\left(\frac{G}{G-N}\right)^2 \delta_G^2 + \delta_F^2 + \left(\frac{N}{G-N}\right)^2 \delta_N^2 + \left(\frac{pF}{G-N}\right)^2 \delta_p^2}. \tag{5}$$

where δ_G, δ_F, δ_N and δ_p are the relative errors in measuring the weight of the piston, the effective area of the piston, the force exerted by the spring mechanism, and the pressure above the piston.

It is clear from (5) that the latter two errors may be made quite small if N and p are chosen appropriately. Then the error of this type of barometer, as of any other piston barometer, is determined mainly by errors in the

load and area. These errors are about 0.001-0.002%, as results [1] for the mercury-piston barometer show.

But (4) and (5) do not give any idea of the response to changes in atmospheric pressure. The response is governed by the following differential equation for the motion of the piston:

$$\ddot{x}+2\beta\dot{x}+\omega_0^2x=f(t). \tag{6}$$

The damping factor β and the natural frequency ω_0 are functions of the parameters:

$$\beta=\frac{\mu l}{rh}\cdot\frac{g}{B};\ \omega_0=\sqrt{\frac{kg}{\pi r^2 B}}. \tag{7}$$

The function $f(t)$ is the law followed by the atmospheric pressure.

The symbols are r, the radius of the piston; l, the length of the gap between cylinder and piston; h, the width of that gap; μ, the viscosity of the working fluid; B, the atmospheric pressure; g, the acceleration due to gravity; and k, the stiffness.

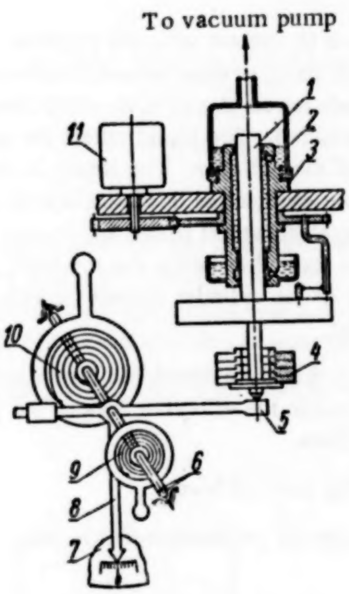


Fig. 1.

If we solve (6) and compare the motion of the piston with the changes in atmospheric pressure, we will get a complete representation of the dynamic errors under various conditions. But the atmospheric pressure changes in a very complex way, and we cannot deal with the resulting dynamic errors here. Therefore we consider briefly only the factors that influence the inertia.

If we use the simplest mathematical form for the law followed by the atmospheric pressure, we find that the parameters should be made such that ω_0 is as large as possible, while β should be as small as possible consistent with the condition that its value is close to that of ω_0. The piston will not show free oscillations, because the viscosity of the liquid in the gap produces a very heavy damping effect.

In view of the above, and in accordance with (7), we may say that the requirements are as follows: the length of the gap and the viscosity of the liquid should be minimized, while the gap, the radius and the stiffness should be as large as possible. The requirement of increased radius derives from (7), since the stiffness can be increased in proportion to the area without affecting the accuracy.

Design. A sub-standard class I barometer has been made which uses the second system. Figure 1 shows the system, and Fig. 2 gives a general view of the instrument.

The sensing part consists of the piston 1, which is lapped into the cylinder 3. The top of this cylinder carries a glass cap 2 fitted with a coupler to connect it to a vacuum pump. Disturbances that might be caused if the piston were turned by hand are eliminated by driving the piston with the motor 11. The drive mechanism is shown here as a roller which works in agate bearings and engages with a ring on the shaft. The lower end of the piston bears the weights 4 and itself operates the lever 5, which has bearings 6, also of agate. The lever carries the needle 8, which is read on the scale 7. The staff of this lever is coupled to the inner ends of spiral springs 9 and 10, one of which is used to produce the stepwise change in the force, and the other of which is used to measure the force within each step.

The set of weights 4 is made in such a way that the smallest weight is equivalent to the maximum force exerted by the spiral springs.

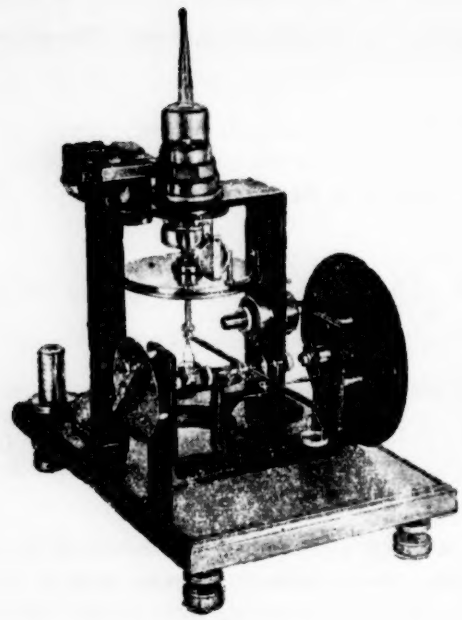


Fig. 2.

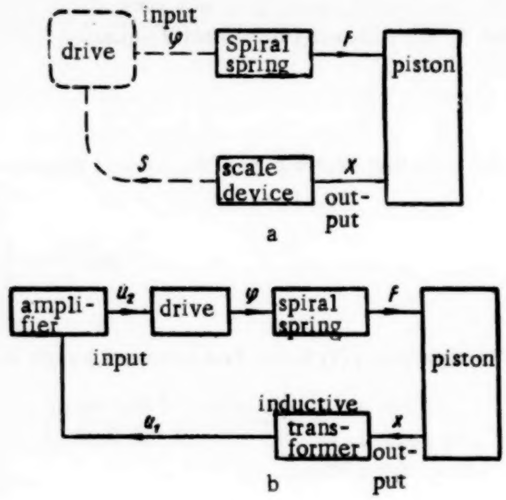


Fig. 3.

The piston is in contact with the cylinder along three narrow bands only, in order to reduce the fractional force. These bands are so placed that, while liquid is present in each gap, the amount of liquid reaching the lower part is minimized. The liquid enters the space between the middle and lower bands from a funnel fixed to the lower end of the cylinder. The liquid in the funnel stands above the lowest band, so no air can enter at that gap. The pressure drop across this band is such as to minimize leakage of liquid. The top band is intended to give stability against lateral forces and to stop the liquid from entering the space above the piston. For this purpose there is a hole somewhat below the top band through which hole the liquid enters between the cylinder and the cap. The body of the cylinder contains a hole, through which the liquid is injected into the funnel via a needle valve (not shown).

The central band serves to maintain the pressure difference between the space above the piston and the outside pressure. The gap size and piston diameter at the central band determine the effective area of the piston. The central band is the main one and is therefore made wider than the others.

The lever carries a pan, in which weights are placed during checking and calibration.

The barometer is enclosed in a sealed box, which is fitted with a pipe for connection to any other barometer.

The range is 0.95-1.05 kg/cm^2 (700-780 mm Hg), the error is 0.002% (0.01-0.02 mm Hg), one division on the scale corresponds to 0.010 g/cm^2 (0.007 mm Hg), the range available on the scale is 0.6 g/cm^2 (0.5 mm Hg), and the total range covered by the spring mechanism is 0.005 kg/cm^2 (4 mm Hg).

The dimensions are 250 × 350 × 300 mm and the weight is 10 kg.

An experimental model of the instrument has been tested at the Institute. The root-mean-square error relative to a standard barometer did not exceed 0.01-0.02 mm Hg.

Piston barograph. Automatic recording instruments (barographs) have come into use recently.

The principle on which the first form of the piston barometer is based is to control the position of the piston. Figure 3a shows the structural diagram of a manually controlled piston. The system is an open-loop one. The output (the position) is coupled to the input (the spiral spring) by the observer. The loop must be closed in order to make the system automatic, i.e., the man must be replaced by a mechanism. Figure 3b shows one possible system for the purpose. Any deviation from the equilibrium position is transformed by the transducer into a voltage, which is amplified and fed to an electric motor. This motor twists the spring until the piston returns to the equilibrium position. The rotation given to the spring, and hence the atmospheric pressure change, is thereby recorded.

The transducer need not be of induction type. Photocell and photoresistor circuits can also be used.

Some preliminary trials show that an automatic control system based on standard units gives high sensitivity. The reversible motor began to drive when the plunger of the transducer was displaced by 0.005-0.010 mm; the speed was proportional to the displacement for small displacements.

An approximate analysis shows that the resulting barograph would not be less accurate than the barometer described above.

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A PHOTOELECTRIC INSTRUMENT FOR MEASURING TORQUES

M. D. Konovalov, V. A. Rikhter and V. N. Tarapin

This instrument was developed to Professor S. A. Strelkov's design for measuring the torques in the shafts of building and road-making machines; the two designs were made to work a loop oscillograph without requiring current leads. The first design was meant for use with shafts that could be withdrawn in order to mount the device; the second (demountable) design was meant for use with shafts that could not be withdrawn.

The device is fed from storage batteries, which is useful under field conditions.

Clamping screws hold two cylindrical units 2 to the shaft 1 (Fig. 1). Each unit carries a disc 3, which has narrow radial slits. These discs are close together and rotate freely with respect to one another. The fixed demountable body 4 is fitted with eight pea bulbs 5 and matt glass 6; on the other side there are photocells 7 arranged to form a continuous ring.

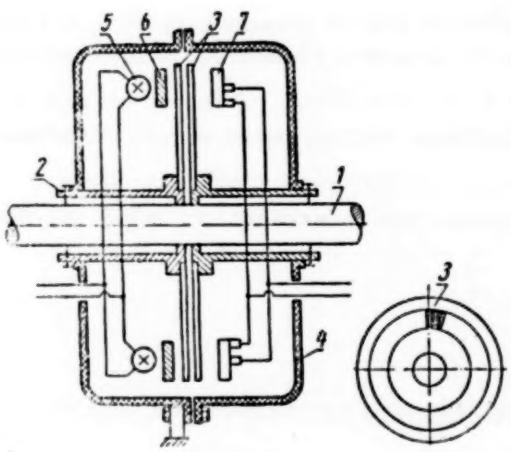

Fig. 1.

The light from the lamps is scattered by the glass and passes through the slits onto the photocells, which produce a current proportional to the light flux. The shaft twists when it transmits a torque, and one disc is displaced relative to the other.

The angle of twist depends on the distance between the held ends of the cylinders 2 that carry the discs 3, on the diameter of the shaft, and on the torque. The size of the gaps depends on the twist, and hence the light reaching the photocells, and therefore the photocurrent, is proportional to the torque.

Instruments meant to measure steady torques can use silver sulfide units, but selenium cells must be used in ones that are to measure transients. Silver sulfide units are highly sensitive, but they give a poor frequency response. Selenium units are less sensitive, but have a better frequency response.

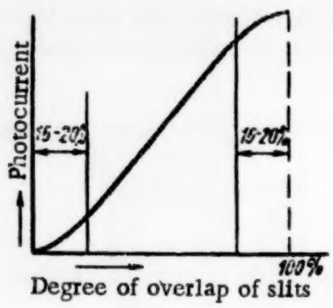

Fig. 2.

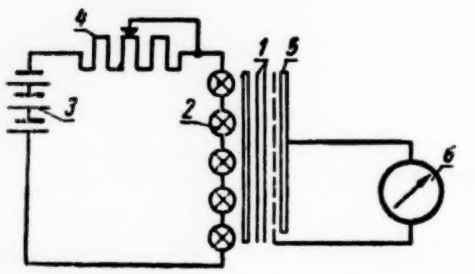

Fig. 3.

Figure 2 shows how the photocurrent depends on the torque (disc displacement). The response is clearly nonlinear; the central linear region is about 60-65% of the whole. It is found that the length of the linear part depends on the care with which the discs are made, on the gap between the discs, and on the general accuracy of the assembly. The slope of the torque response curve is determined by the width and a number of the slits, by the distance between the clamping points, and by the diameter of the shaft. The sensitivity increases as the diameter decreases, as the slits are made narrow, and as the distance is increased.

The error can be made small if the linear part is used and if the current decreases as the torque increases (if the slits overlap less). The zero-torque point may be set at the start of the straight section by setting the discs so that the slits are covered up to 15-20% when the torque is zero; the slits must be covered up further as the torque increases. The zero point is set at the middle of the linear section when shafts subject to torques of both senses are used by setting the slits to overlap 50% at zero torque.

Figure 3 shows the circuit. The unit is set up on the shaft and the discs 1 are set in an appropriate position; the lamps 2 are connected to a battery 3 via a rheostat 4, while the photocells 5 are connected to a galvanometer of other recording instrument 6. The rheostat is adjusted to give the maximum useful photocurrent with zero torque and provides a means of zero setting. The unit may be calibrated by applying known torques to the shafts. The photocurrent decreases as the torque increases.

The zero point is reset with the rheostat before the series of actual measurements is started.

This method of adjusting the lamp supplies eliminates effects caused by ageing in lamps or photocells, or by temperature changes, while providing a simple means of adjustment.

SUMMARY

Tests have shown that the calibration stays unchanged (within the error of measurement) for up to a year; the error of measurement under field conditions is 3-4%, but can be reduced to 2% under laboratory conditions; the unit works well at temperatures from −20 to +35°C.

These units have been in use for several years on excavators, snow-clearing machines, road rollers and other such machines.

From the Editor. V. I. Zelinskii has used the principle described here to make the torsion gage described as "A photoelectric torque torsiometer" in No. 1 for 1958.

A BALLISTIC PENDULUM FOR CALIBRATING ACCELERATION TRANSDUCERS

V. P. Nenyukov, A. S. Zhmur and G. L. Lyapin

The ballistic pendulum (Fig. 1) consists of a framework, a striker, a release mechanism and a deflection meter.

The striker is a steel cylinder held by four steel wires. It is fitted with a striking pad on one end and with lugs and chain to couple with the release mechanism on the other.

The counterweight is made of cast aluminum and is suspended in the same way as the striker. The end facing the striker can be fitted with a disc of steel, plastic etc. The other end carries a holder for the transducer. The weight is also fitted with a boss coupled to a wire that works the deflection indicator.

Fig. 1.

We found by recording the signals from a piezoelectric transducer on an oscilloscope that vibrational oscillations were excited in the weight. The accelerations caused by these oscillations are superimposed on the general acceleration. A cleaner recording (Fig. 2) was produced by fitting a damping pad between the weight and the transducer holder.

The shape of the acceleration pulse produced when the impact disc is of bonded plastic is fairly close to half a sine wave (the area under the curve deviates from the area for the best-fit sine wave by not more than 4%).

In this case the maximum acceleration is [1] given by

$$W = \frac{\pi V}{2g\tau}, \tag{1}$$

where V is the maximum speed of the weight and τ is the time of contact with the striker.

Fig. 2.

An electronic chronograph may be used to measure τ.

We may find the above maximum speed from

$$V = \frac{M_2(1+k)V_M}{M_1+M_2}, \tag{2}$$

where M_1 is the mass of the counterweight, M_2 is the mass of the striker, V_M is the maximum speed of the striker before the impact, and k is the restitution coefficient.

The restitution coefficient may be found from the height h to which a steel sphere released from a height H rebounds from a thick plate:

$$k = \sqrt{\frac{h}{H}}. \tag{3}$$

The maximum speed of the weight is given by

$$V = L\sqrt{\frac{2GL(1-\cos\alpha)}{I}}, \tag{4}$$

where α is the deflection produced by the blow, G is the mass of the weight, L is the distance from the center of gravity to the rotation axis, and I is the moment of inertia of the weight about that axis.

This moment of inertia may be measured by oscillation methods to be

$$I=\frac{T^2}{\pi^2}GL. \tag{5}$$

where T is the half-period of such oscillations.

The acceleration can be found directly by integrating the area under the oscillogram curve when the maximum speed is known.

We have

$$V=\int W dt, \tag{6}$$

and the abscissa of the oscillogram may be expressed in a time scale defined by

$$t=k_t n, \tag{7}$$

where k_t is the time-scale factor and n is the length of the oscillogram along the time axis, while the ordinate is given in the acceleration scale as

$$W=k_w m, \tag{8}$$

where k_w is the acceleration-scale factor and m is the ordinate of the recording, so

$$V_H=k_w k_t \int m dn=k_w k_t F,$$

where F is the area under the curve.

Therefore the acceleration-scale factor is given in terms of g by

$$k_w=\frac{V}{k_t g F}. \tag{9}$$

It is best to enlarge the record in order to measure the area and time scale accurately.

Figure 2 was taken with a weight weighing 38 kg. The center of gravity was 1.48 m from the point of support.

Then I = 8.72 kg · sec^2· m.

The deflection was 26°, so V = 1.78 m/sec.

The time marks have a frequency of 2140 cps, with adjacent marks 33 mm apart; hence k_t = 1.42 × 10^{-5} sec/mm and k_w = 5.06 g/mm.

The peak height h_1 = 46.5 mm, so the acceleration was 235g.

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A LIGHT-WEIGHT LABORATORY SCELEROMETER

Yu. N. Andreev

We have made a light-weight laboratory scelerometer for use with materials whose static and dynamic moduli of elasticity do not differ greatly.

The instrument has a glass tube 500 mm high and of internal diameter 10 mm. The tube is graduated at 5 mm intervals. The tube is held in a support that allows it to rotate freely in two mutually perpendicular directions. The support is fitted with three levelling screws. The base is set horizontal and the tube vertical by means of plumb-bobs. The tube is lifted by a worm drive that does not deflect it from the vertical.

The sample is held on the base by special clamping plates. The tube is brought into contact with the sample and a steel ball (weight 0.5 g) is dropped down the center. The height to which the ball bounces is estimated by eye. To determine the mean height it is necessary to make 20 measurements. The mean height so found is reproducible.

Lighter balls are used if balls of the above weight mark the sample.

The height to which the ball bounces depends on the surface treatment in the case of carbon steel. Therefore we have estimated the roughness of a polished glass surface with a copper replica. Of two forms of flat engraving on zinc, one was suitable for printing and the other was scrap. Studies with the above scelerometer gave the following results.

The good one gave a rebound of 8.9 cm, whereas the scrap one gave a height of 4.8 cm. This result was confirmed on various printing plates. In each case a good plate gave a height about 2 times as large as a useless one did. This provides a rapid method of testing printing plates.

SUMMARY

The scelerometer enables one to estimate the relative hardness of a material, and to measure the mean height of the ridges on glass and metal surfaces.

HEAT MEASUREMENTS

STABILITY OF THE DISTILLATION TEMPERATURE OF CARBON DIOXIDE

V. A. Usol'tsev

Two of the main points on the international temperature scale (0 and 100°C) are readily reproduced and are often used for testing metrological thermometers. It is more difficult to do such tests at temperatures below zero.

The closest primary reference point on the international scale is −182.97°C, whereas the lowest temperature for which metrological (aerological) thermometers are intended is about −90°C. There is thus a long gap between the temperatures at which the thermometers should be checked and the nearest reference point. Also, special apparatus and pure liquid oxygen are needed to reproduce the −182.97°C point. A secondary reference point near −100°C is thus desirable.

A useful point for the purpose is the temperature at which solid and gaseous carbon dioxide are in equilibrium at atmospheric pressure (the distillation point of carbon dioxide) [1-3].

Certain precautions have to be taken to get good results with this point. The temperature taken up by the CO_2 depends on the partial pressure of carbon dioxide in the gas above it. The temperature may differ substantially from normal if air is present. Powdered carbon dioxide placed in a dewar at first takes up a temperature several degrees below the normal value. Then, as the air is gradually eliminated, the temperature rises to the normal value. The process is very slow and may take over 10 hours to go to completion.

Theeffect is the same if the carbon dioxide is mixed with a liquid of low freezing point [3]. Temperatures down to −85°C have been produced in liquid baths with solid CO_2 in this way [4]. The bath consists of finely ground dry ice in trichloroethylene, through which air is blown.

Some data [3] indicate that the point can be reproduced with an error of 0.01°C. It is also predicted that the temperature will not depend appreciably on the content of the impurities normally present in technical dry ice.

The carbon-dioxide point has [5] been listed among reference points. But here there is no description of how the point is to be reproduced, and no data are given on the stability of that point.

To establish whether the CO_2 point can be used for thermometry, and to clear up a number of aspects of the method of reproducing that point, we have examined the stability of the distillation temperature of carbon dioxide.

We used a 100-ohm TSPV-48 thermometer, calibration 12a, whose error did not exceed ±0.01°C, to measure the equilibrium temperature attained by solid carbon dioxide in contact with its own vapor. The resistance was measured potentiometrically.

The TSPV-48 thermometers were selected from their ice-point resistances. The thermometer finally used for all the measurements was connected through four wires 0.2 mm^2 in area coated with PVC. The points at which the leads were soldered to the base of the thermometer were protected from moisture with rubber strips. The length of lead above the solid carbon dioxide was never less than 300 mm.

Dewars of various sizes were used for the measurements.

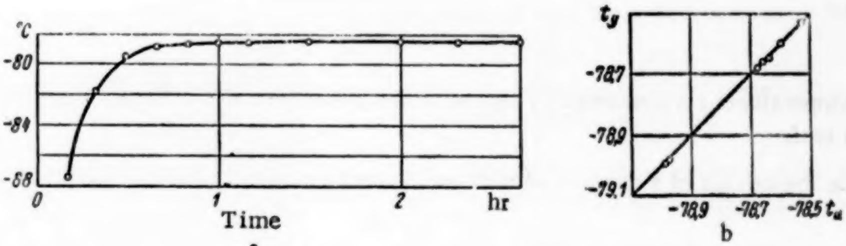
The best results were obtained with vessels 115 mm in diameter and 400 mm high. We did 8 runs with this vessel; in each case the vessel was filled to the top with powdered carbon dioxide, and a heater was placed near the bottom at 6-8 cm from the TSPV-48.

The supercooling effect was detected in the first two runs by switching on the heater only after an hour had elapsed. This demonstrated the effect clearly, and in future the heater was switched on almost as soon as the vessel had been filled.

When the vessel had just been filled and the heater was switched on the temperature was 9.1°C below the equilibrium value (see Figure, a). Supercoolings as large as this did not occur every time, but they were common. Only in one case (when the leads were not properly attached) were the readings not low. The supercooling effect implies that a certain definite technique must be adopted in reproducing this point.

In the Figure (part b) we show the temperatures calculated and measured after equilibrium had been reached. In no case does the difference exceed 0.01°C, and in only one case out of eight is the difference as large as 0.01°C.

Therefore the large dewar (one whose dimensions are comparable with the thermometer's) gave entirely satisfactory results. In all cases we detected only minute changes in temperature once equilibrium had been reached. We found no random deviation of the measured temperature t_u from the calculated ones t_y.



a b

In the first three runs the heater was supplied with 10 w. After 3 min the power was reduced to 3 w. In the first two runs the heater was switched on 1 hour after the carbon dioxide had been added. In all other runs the power was much larger. Initially it was 23 w, followed by 10 w after 12 min. The increased power reduced the time needed for equilibration. The reduction in the time was not proportional to the power, though. Larger powers were not used because of the danger of damage to the dewar.

The later runs showed that the time needed for the temperature to settle down varied from 12 to 60 min. In one case, in which no supercooling was detected, the time was 1 hr 28 min. In every case the steady temperature finally reached agreed with the calculated temperature to 0.01°C.

The lowest atmospheric pressure during the runs was 729.0 mm Hg; the highest was 759.4 mm Hg. In nearly all cases the solid carbon dioxide was the white odorless technical product. In two cases it was yellowish and had a strong smell of hydrogen sulfide. No effect on the temperature was detected, though.

SUMMARY

1. The tests show that the sublimation temperature of solid carbon dioxide may be used as a convenient secondary reference point.

2. Fairly high accuracy and good stability are found when this point is reproduced in an appropriate way. The error involved is about 0.01°C. The method employs a large dewar and operations conducted in a strict sequence. The best results are obtained if supercooling occurs at the start.

3. The presence of air in the atmosphere around the solid affects the sublimation temperature. Methods that do not ensure that this effect is eliminated should not be used. In particular, methods involving solid carbon dioxide in alcohol or other liquids should not be used, nor should powdered carbon dioxide be used without allowing its temperature to settle down.

4. Different batches of dry ice from the same source showed no effect from impurities on the temperature, within 0.01°C limits.

5. The results show that this point may be used to check thermometers, which is a feature of considerable value in work in the range from 0°C to −80°C.

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[3] R. Scott, Temperature, New York, 1941, p. 206-218.

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THREE-CHANNEL AMPLIFIER EQUIPMENT FOR THERMOCOUPLES

A. A. Aref'ev

When variable temperatures are measured by means of thermocouples and loop oscillographs it is necessary to amplify the thermal emf.

Below we describe the circuit of a channel of a three-channel equipment 3-UT-1 designed for the above purpose.

The schematic of the channel is shown in Fig. 1. The thermal emf is fed to terminals 1 and 2 of J1 and converted by means of a ring transducer consisting of copper oxide rectifiers VK-07 into an alternating voltage which is then amplified by means of a three stage electron amplifier which uses 6N9S and 6S2S tubes. The amplified voltage is fed from the output transformer to a ring rectifier and then through a filter to the oscillograph vibrator

For balancing the transducers galvanometer G is connected to the output of the amplifiers by means of switch S_2.

Resistors R_1, R_2 and R_3 are connected in series with the vibrator and provide the dc negative feedback.

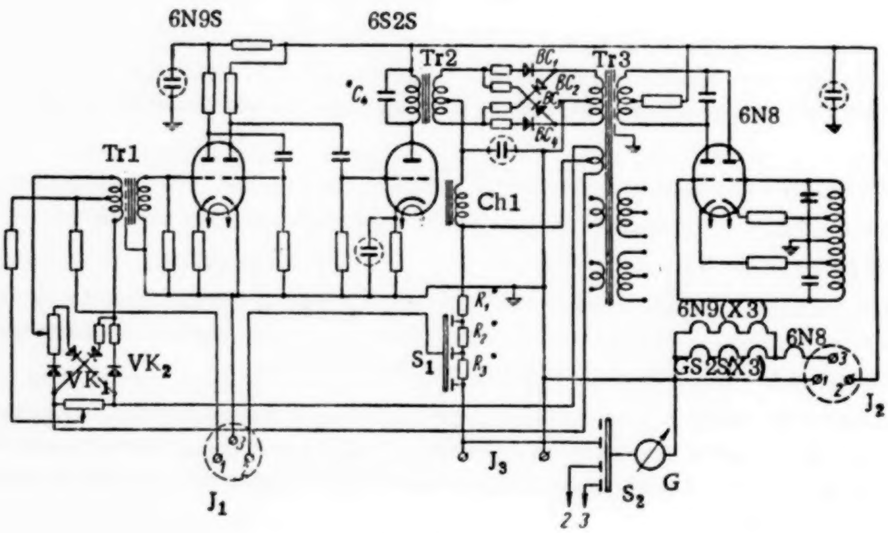

Fig. 1.

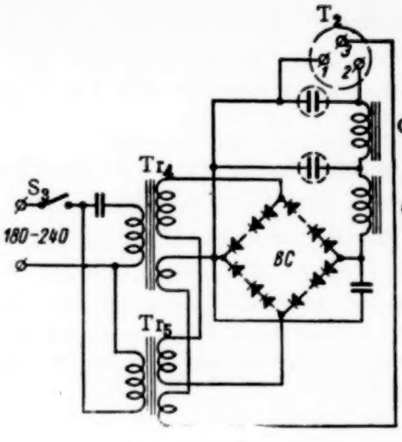

Fig. 2.

Fig. 3.

The resistors R_1, R_2 and R_3 are selected in such a manner that the drop of potential across them roughly corresponds to the measured thermal emf. Hence the negative feedback coefficient is made to approach unity.

Final values for resistors R_1, R_2 and R_3 are fixed when the equipment is adjusted for operation.

The measuring ranges are changed by adjusting the feedback with switch S_1.

The 3 kc modulating voltage for the ring transducer and rectifier is provided by a 6N8 tube used as a push-pull oscillator with a tuned grid circuit.

The oscillator and amplifier supplies are provided through a ferroresonance stabilizer (Fig. 2).

The dimensions of the set are 305 × 140 × 150 mm (Fig. 3).

The rectifier together with the ferroresonance stabilizer are mounted in a separate unit connected to the main set by a cord.

The equipment has three measuring ranges: $0\text{-}6 \cdot 10^{-3}$ v, $0\text{-}12 \cdot 10^{-3}$ v and $0\text{-}18 \cdot 10^{-3}$ v.

Variations in the resistance of the thermocouple circuit from 0 to 200 ohms does not cause an error greater than ±1%.

The output current into a resistance of 3.5 ohms is 70 ma. The amplifiers are designed to work with MOV-1 vibrators.

The deviation of the output current from linearity does not exceed ± 0.5 ma.

The amplifier characteristic is flat in the range of 0 to 100 cps. The gain instability during one hour does not exceed 1%.

Variations of the ambient air temperature from +20 to +40°C does not produce any noticeable effect on the output current of the amplifier.

INVESTIGATION OF ELECTROLYTIC THERMOCOUPLES

S. A. Sukhov, S. Ya. Kadlets and G. D. Pavlyuk

If a length of wire made of a certain metal (for instance, constantan) is electrolytically covered by a layer of another metal (for instance, copper) a so-called electrolytic thermocouple is obtained in which the end points of the covered length serve as junctions (Fig. 1).

P. D. Lebedev [1] states that the electrolytic thermocouple produces the same emf as a point welded thermocouple of the same metals. He does not point out, however, that the voltage u in the external circuit of an electrolytic thermocouple is smaller that the thermal emf even when the external circuit is open and that this voltage depends on the thickness of the covering layer.

This can easily be demonstrated if we assume for the sake of simplicity that the covering layer has an electrical contact with the wire only at the ends of the length (Fig. 2). In this case the covering layer can be replaced by a wire of the same metal fixed to the main wire at two points (Fig. 3). Let us call this a double thermocouple. If the junctions are at different temperatures contact potential differences u_1 and u_2 will arise in them. Their algebraic sum provides the thermal emf

$$\epsilon = u_1 - u_2,$$

which will produce in the circuit consisting of a length of the main wire of resistance R_1 and the additional wire of resistance R_2 a current

$$I = \frac{\varepsilon}{R_1 + R_2}.$$

Moreover across points a and b in the open external circuit there will be a voltage equal to the potential drop in the resistance of the main wire length and determined from the formula

$$u = IR_1; \quad u = \frac{\varepsilon}{1 + \frac{R_2}{R_1}}. \tag{1}$$

Whence it follows that:

1) whereas the open circuit voltage of a normal thermocouple is equal to its thermal emf ϵ, that of a double thermocouple is always smaller than ϵ. This is due to the internal voltage drop in double thermocouples,

2) u depends on the thickness of the additional wire, with a rising thickness R_2 drops and the value of u approaches that of ϵ,

3) the ratio of voltage u to the thermal emf is determined only by the ratio of the resistance of the additional wire to that of the main wire and does not depend on the materials they are made of,

$$\frac{u}{\varepsilon} = \frac{1}{1 + \frac{R_2}{R_1}}. \tag{2}$$

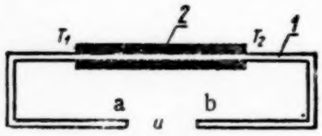

Fig. 1. 1) Main wire; 2) covering.

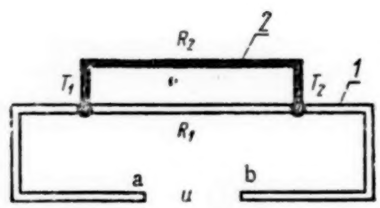

Fig. 3. 1) Main wire length of resistance R_1; 2) additional wire length made of another material of resistance R_2.

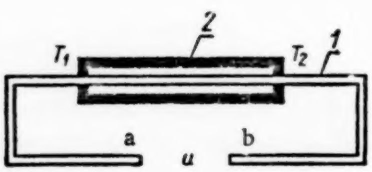

Fig. 2. 1) Main wire; 2) covering.

The electrolytic thermocouple differs from the double one by its covering being in electrical contact with the main wire not only at the ends but along the whole length. Nevertheless qualitatively an electrolytic thermocouple behaves like a double one. This has been confirmed by our experiments.

Electrolytic thermocouples of the following materials have been investigated (the first material is that of the main wire and the second that of the covering): constantan–copper, nickel–copper, copper–nickel.

The relation of voltage u at points a and b to the thickness of the covering layer and the diameter of the wire were investigated.

Test results obtained by the additional resistance and balancing methods leads to the following conclusions:

1) in agreement with the circuit shown above the voltage at the ends of an open external circuit of an electrolytic thermocouple is always smaller than its thermal emf and depends on the thickness of the covering;

2) an increase in the thickness of the covering (and hence a decrease in its resistance) increases u making it approach the thermal emf for the same materials, which agrees qualitatively with (1);

3) in order to make an electrolytic thermocouple with a thin covering and a voltage u approaching its thermal emf it is advisable to use for the main wire a metal with a high resistivity, for instance, nickel ($\rho = 0.073 \cdot 10^{-4}$ ohm · cm) and make the covering of a metal with a low resistivity, for instance, copper ($\rho = 0.017 \cdot 10^{-4}$ ohm · cm). If copper wire is covered by a layer of nickel, then even with a considerable thickness of the nickel layer voltage u will only be a small faction of ϵ. For instance with a nickel covering of 74 μ over a copper wire 0.8 mm in diameter, voltage u only amounted to 1 μv/degree, whereas the thermal emf of a nickel copper thermocouple is equal to 23 μv/degree;

4) if the diameter of the main wire is decreased (i.e., its resistance increased) the thickness of the covering must be decreased in order to keep the voltage constant. This conclusion agrees qualitatively with (1). In order to obtain a voltage of 1 μv/degree it is sufficient to deposit a layer of nickel 37 μ thick over a copper wire 0.5 mm in diameter, whereas a nickel layer of only 20 μ is required for a copper wire 0.34 mm in diameter.

Hence, whereas the open circuit voltage of a point thermocouple is equal to its thermal emf and has a definite value, the voltage of an electrolytic thermocouple is a function of the main wire diameter and the covering thickness. With an available couple of metals it is possible to make electrolytic thermocouples with any voltage from 0 to ϵ.

The electrolytic thermocouples have the defect of changing their voltage during the course of their operation as the covering layer becomes thinner (due to wear, oxidation etc.). In certain cases, however, the use of electrolytic thermocouples can be advantageous. For instance it is impossible to make point thermocouples from metals with good thermoelectric properties if they are brittle and do not lend themselves to drawing into wires. These metals, however, can be used for coverings in electrolytic thermocouples. Thus a possibility arises of making coatings of semiconductors which have high thermoelectric parameters. On the other hand electrolytic thermocouples can be used for measuring thermoelectric parameters of other materials.

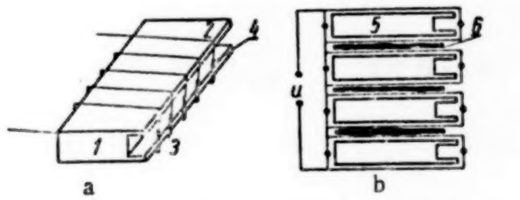

Fig. 4. a) Cross section of a thermopile: 1) frame, 2) uncovered half-turns, 3) covered half-turns, 4) junctions; b) a thermopile consisting of four sections 5) separated by packing 6).

Finally electrolytic thermocouples can be used in the following manner developed by us for making thermopiles. A thin wire is wound over a plastic frame (Fig. 4a) the number of turns being limited by the thickness of the wire and dimensions of the frame. The distance between the turns should be large enough to prevent the wires touching when coated. The upper part of the frame is covered with paraffin wax or another insulating material and the open lower portions of the turns are degreased and electroplated with another metal which provides a high thermal emf between it and the wire and which has a resistivity lower than that of the wire (for instance, constantan wire is covered with copper). As the result of it thermopile sections are obtained which have their odd and even junctions on opposite sides of the frame. By connecting in series several such sections it is possible to obtain a thermopile consisting of hundreds, even thousands of thermocouple junctions (Fig. 4b). Such a thermopile is simple to make and possesses a high sensitivity.

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EQUIPMENT FOR TESTING INSTRUMENTS AT VARYING TEMPERATURES

A. V. Marsov

In testing the effect of high and low temperatures on the metrological characteristics of analytical balances the SKB-1 (Leningrad) used equipment which was simple to make and did not require large capital outlays.

Temperatures between 0 and −70°C were obtained in a refrigerator of simple construction which worked on liquid nitrogen. The refrigerator dimensions are 1.13 × 1.13 × 1.13 m. The volume of the internal chamber is 1 m^3; it is lined with galvanized iron. The body of the refrigerator is made of wood and covered with plywood 7 mm thick. The sides, bottom and top of the cabinet are of a cavity type, the 13 cm spacing between the two walls is packed with a lagging material – building felt (glass wool or other materials can be used). The door is made of seven layers of window glass; the door gaps are tightly packed with building cloth.

The upper portion of the chamber contains a galvanized iron movable vessel fixed on brackets which serves to evaporate liquid nitrogen inside the chamber. The roof and sides of the chamber contain several funnel-shaped holes for pouring-in nitrogen and fixing thermocouples or thermometers, supplied with the chamber. The liquid nitrogen is kept in a 15 liter Dewar flask which provides 10 m^3 of gaseous nitrogen.

Experience in using this refrigerator has shown that an appropriate use of liquid nitrogen can ensure a constant temperature during many hours with an accuracy of ±1°C; the small amount of liquid nitrogen used makes this equipment economical in operation. Thus for maintaining in the chamber a temperature of −50°C for 3 hours 45 liters of liquid nitrogen were required at a total cost of 21 roubles.

It is possible to make the supply of liquid nitrogen to the chamber pipes automatic.

For obtaining high temperatures electric heaters were used with contact thermometers which automatically provided the maintenance of the required temperature.

This equipment reproduced efficiently the required transport and operational temperatures for analytical balances being tested for temperature stability of their metrological characteristics and can be recommended for similar tests of other instruments.

RESULTS OF COMPARING TEMPERATURES CALCULATED BY THE MShT AND THE COMPARISON METHOD

P. G. Strelkov and D. I. Sharevskaya

A method of calculating the temperature of a platinum resistance thermometer in the range of 0 to −200°C by the standard $W^{cm}(t)$ table based on Matthiesens rule is suggested in [1]. For the calculation of temperature one constant is required, which is obtained from calibrating the thermometer at two points (0°C and 182.97°C).

The error of the suggested comparison method is very close to that of the MShT in the region of 0 to −183°C and it is due to the instability of thermometers and errors of calibration. The difference in temperature calculated by the MShT and by the comparison method amount to some 0.01°C.

In Table 2 of [1] a comparison is made between temperatures calculated by the MShT and the comparison method for 4 thermometers. Below we provide similar comparisons for another 19 thermometers both home and foreign made.

The data in this table confirms the evaluation of the comparison method error and the divergence between scales given in [1]: the maximum differences lie between 0.001° and 0.014°C. The arithmetic mean of the maximum temperature differences calculated by the MShT and by the comparison method for all the 22 thermometers amounts to 0.0070.

Thermometer constants			Temperatures calculated by the comparison method, °C			
			for all thermometers	−50.000	−100.000	−150.000
α	δ	β	for thermometers Nos.	temperatures calculated by the MShT °C		
0,00390475	1,4966	0,1116	A¹⁾	−49.999	− 99.999	−150.004
1326	4986	1130	C¹⁾	−50.006	−100.010	−150.012
1346	5116	1218	E²⁾	−50.052	−100.080	−150.064
1560	4938	1108	F¹⁾	−49.994	− 99.990	−149.999
2140	4977	1124	B¹⁾	−50.004	−100.005	−150.009
2457	4950	1109	D¹⁾	−49.995	− 99.992	−150.000
2435	4899	1125	№103³⁾	−49.999	− 99.998	−149.998
2380	4914	1122	№104³⁾	−49.998	− 99.995	−149.997
2405	4920	1105	№105³⁾	−49.992	− 99.986	−149.989
2485	4908	1114	№106³⁾	−49.995	− 99.991	−149.992
2385	4902	1119	№107³⁾	−49.998	− 99.997	−149.999
2410	4914	1118	№109³⁾	−49.997	− 99.994	−149.996
2365	4904	1122	№113³⁾	−49.998	− 99.996	−149.997
2375	4914	1114	№117³⁾	−49.995	− 99.992	−149.994
2498	4889	1131	№1 (Iks-6)⁴⁾	−50.001	−100.002	−150.001
2594	4914	1109	№2 (Iks-6)⁴⁾	−49.992	− 99.986	−149.988
2528	4906	1121	№3 (Iks-6)⁴⁾	−49.998	− 99.996	−149.996
2438	4905	1126	№4 (Iks-6)⁴⁾	−50.000	−100.001	−150.001
2450	4908	1123	№5 (Iks-4)⁴⁾	−50.001	−100.001	−150.001

1) Data taken from the work of H. I. Hoge, and F. G. Brickwedde Jour. of Res. NBS, 28, 217, 1942.
2) Data taken from the same work. Thermometer does not satisfy the 1948 MShT requirements.
3) Data taken from the work of N. A. Brillinatov, P. G. Lin'kov and P. G. Strelkov entitled "Temperature Measurements" Proc. MGIMIP issue 3, Mashgiz 1950.
4) Thermometers of the thermal laboratory of VNIIFTRI.*

* Publ. note: VNIIFTRI = All-Union Scientific Research Institute for Physicotechnical and Radiotechnical Measurements.

The thermometer of Brickwedde and Hoge which does not satisfy the additional (MShT 1948) requirements has been excluded from consideration by them and differs considerably from the others.

LITERATURE CITED

[1] P. G. Strelkov, and D. I. Sherevskaya, Measurement Techniques, No. 6 (1957).

MEASUREMENT OF THE GYROMAGNETIC RATIO OF A PROTON IN A WEAK MAGNETIC FIELD

B. M. Yanovskii, N. V. Studentsev and T. N. Tikhomirova

Paramagnetic nuclear resonance is at present widely used for measuring magnetizing force. From relation

$$\omega = \gamma H, \tag{1}$$

where ω is the precession of the paramagnetic nuclei in the magnetic field H, and γ is a constant called the gyromagnetic nuclear ratio, the value of the magnetizing force is determined by measuring the frequency when the gyromagnetic nuclear ratio is known. Hence for practical magnetic measurements the value of γ must be known, and it can only be determined experimentally. Relation (1) shows that γ can be found if ω is measured in a known magnetic field.

In the VNIIM* magnetic measurements laboratory work is being conducted at the present time for determining the value of the gyromagnetic ratio of a proton by means of the free nuclear induction method. Helmholtz rings serve as a source of the magnetic field whose intensity can be determined by the current flowing through the rings and their geometrical dimensions from the relationship

$$H = KI,$$

where K is the constant of the rings and, I the current flowing through their windings. The Helmholtz rings used in these tests consist of quartz cylinders some 30 cm in diameter wound with bare wire. An accurate value of the parameters of one of the five rings is given in the table attached.

Distance between the mean planes of the windings, mm	Mean diameter of the wire, mm	External diameter of the windings, mm			
		I belt		II belt	
		I generatrix	II generatrix	I generatrix	II generatrix
135.008±0.002	0.9470±0.0003	270.658±0.002	270.660±0.002	270.712±0.002	270.702±0.002

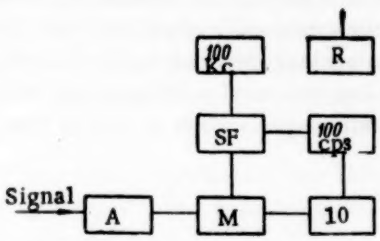
The value of the constant of this coil referred to its center is K = (0.666300 ± 0.000020) Oe/amp.

The current in the windings is measured by a balancing method with an error of the order of $1 \cdot 10^{-3}$%. This accuracy was attained by means of enclosing the standard element and resistance in a thermostatically controlled chamber.

A glass cube of a volume of 8 cm^3 filled with distilled water is used as a transducer for measuring the magnetizing force. The irregularities of the Helmholtz ring magnetic field in such a volume do not exceed $2 \cdot 10^{-3}$%.

* Publ. note: VNIIM = All-Union Scientific Research Institute of Metrology.

The value of frequency ω is measured by beating the nuclear frequency against a standard frequency. The block schematic of the circuit for measuring this frequency is shown in the figure attached.



Frequency measuring circuit. R is the receiver, LO is the loop oscillograph, M is the mixer, SF are standard frequencies, and A is the amplifier.

In order to be able to measure accurately the difference frequency it is necessary to have the standard frequency close to the precession frequency of the nuclear spins. This frequency is obtained by means of dividing the crystal oscillator frequency which is periodically checked against a standard frequency received by the radio receiver R. The error of these standard frequencies does not exceed 10^{-4}%. The measured and standard frequencies are fed to the mixer, M. The difference frequency is recorded on a film of a loop oscillograph which also records time signal pips every 0.01 sec.

Since the measurements are made in the magnetic field of the earth the frequency of the nuclear precession corresponds to the value of the vector sum of the magnetic field intensity of the coil and the earth. Hence in order to exclude the earth's magnetic field, intensity measurements are made with the current in the coil flowing in two opposite directions. In this instance the gyromagnetic ratio can be expressed by the formula:

$$\gamma = \frac{2\pi}{\kappa I}\sqrt{\frac{f_1^2+f_2^2}{2} - f_3^2}\,(1+\Sigma p_i). \qquad (2)$$

where f_1 and f_2 are the frequencies corresponding to the two current directions in the coil, f_3 is the frequency of the nuclear signal in the magnetic field of the earth, Σp_i is the sum of the correcting terms.

Measurements were made in a surburban laboratory at Kavgolovo where is was possible to record the variations in the earth's magnetic field components which form part of the correcting terms in (2).

The laboratory plans to measure the gyromagnetic ratio of the proton with the magnetic field of the earth balanced out. The measuring technique will then be considerably simplified.

The first determination of the gyromagnetic ratio of the proton made with the Helmholtz rings whose parameters are given in the table produced the following value

$$\gamma = (2.67520 \pm 0.00015) \cdot 10^4 \text{ sec}^{-1} \cdot \text{Oe}^{-1}.$$

Above error has in the main a random nature and is due to the error of reading the loop oscillograph film and of the variable instruments.

The value of the gyromagnetic ratio of the proton was determined by the method of forced nuclear resonance by Thomas and others (USA) in a field of an electromagnet of some 5,000 Oe and by Wilhelmy (Germany) in a field of a solenoid of some 100 Oe. The following data was obtained:

$(2.67523 \pm 0.00006) \cdot 10^4 \text{ Oe}^{-1} \cdot \text{sec}^{-1}$ [1]
$(2.67549 \pm 0.00008) \cdot 10^4 \text{ Oe}^{-1} \cdot \text{sec}^{-1}$ [2]. All the values of γ are given without a diamagnetic correction.

In comparing the value of γ obtained by us by the method of free nuclear induction in a field of 0.6 Oe with the values obtained in [1] and [2] we find that it differs from them by an amount of the order of the difference between the two latter results.

The measurement of the gyromagnetic ratio of the proton by the method of free nuclear induction has the advantage over the method of forced resonance in providing the possibility of calculating the field intensity H from the geometrical dimensions of the coil which can be determined fairly accurately. Whereas in the method of forced resonance [1] the magnetic field intensity is determined experimentally by measuring interaction force between the magnetic field and the field of a current carrying coil. Hence in the latter method there are many

more sources of systematic errors. The measuring method of [2] has the drawback of using 10 amp in order to produce the required field, and an accurate measurement of such a current is difficult.

The Khar'kov State Institute of Measures and Measuring Instruments is determining the gyromagnetic ratio by a method similar to [1]. The results of the work of the KhGIMIP and the VNIIM which are using different methods may not only be of interest for determining the numerical value of γ but also for evaluating the accuracy of reproducing the absolute ampere. In method [1] the value of the current measured in the experiment is used in the numerator of the formula for calculating γ, and in the method of free nuclear induction in the denominator. Thus the systematic error in reproducing the absolute ampere will in the first case tend to increase the value of γ and in the second case to decrease it, if the error in measuring the remaining parameters is smaller than the systematic error in measuring current.

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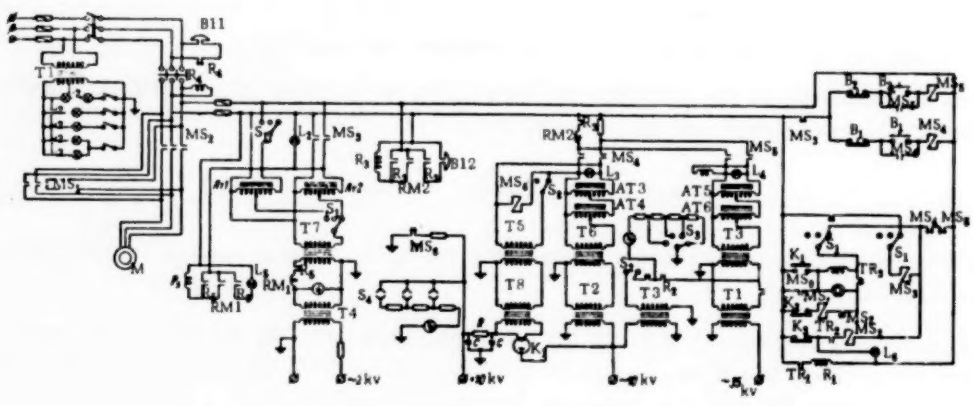
[1] Thomas, Driscoll and Hipple, Phys. Rev. 78, 787, 1950.

[2] W. Wilhelmy, Ann. Phys. 6 Folge, Bd. 19, 329, 1957.

HIGH VOLTAGE TEST GEAR

Yu. Ya. Donde

The equipment consists of two completely independent parts, one of them for testing high voltage measuring instruments and the other for testing electric strength of insulation. It was made in the inspection and measuring laboratory of the Moscow lamp plant with the participation of I. S. Nefedov, A. V. Podgurskii and É. A. Matskevich.



Schematic of the equipment. AT1-AT6 are auto-transformers type LATR-1; T1-T10 are transformers, MS_1-MS_6 are magnetic starters, B_1-and B_2 are starter push buttons, K_1, K_2 and K_3 are wafer switch contacts, S_1 is a three-position four-pole switch, S_2 is a double-throw double-pole switch, S_3, S_4 are standard voltmeter range switches, V_1, V_2 and V_3 are voltmeters, C is the capacitor, R is a resistance T_1 a diode rectifier, L_2 to L_6 are signal lamps, L_7 is a local illumination lamp, M is an induction motor, TR_0, TR_1, TR_2 and TR_3 are time relays, RM1 and RM2 are maximum current relays, R_1 to R_5 are relays, B11 and B12 are alarm bells, K is kenotron.

Checking instruments up to 10 kv ac. The circuit for checking instruments up to 10 kv ac is conventional. Its main components are: autotransformers AT3 and AT4, transformers T6 and T2, an instrument transformer T3 (NOM-10) and a standard voltmeter V_2. The operation of these components requires no explanation.

Checking instruments between 10 and 35 kv ac. In the 35 kv circuit of this equipment the usual special step-up transformer is absent. Its place is taken by the instrument voltage transformer T1 (NOM-35) which performs both functions. The low voltage winding of this transformer is fed with a controlled (in the limits of 100 v) supply. The standard voltmeter which is used for measuring, is connected to this winding as well.

The measured instrument is connected to the high voltage windings of the instrument transformer. The load on the high voltage winding of the transformer is small, since by its means only electrostatic instruments are measured, whose capacity does not exceed a few $\mu\mu f$. Under these conditions the use of the NOM-35 transformer which is designed for a considerable power (1,200 w), simultaneously for stepping-up and measuring, is permissible.

The instrument transformer NOM-35 used in this equipment was checked specially by the VNIIK for stepping-up voltage into a reactive potential divider consisting of two capacitors. Their total capacity amounted to some 100 $\mu\mu f$.

A grade 0.5 instrument with ranges of 10, 25, 50 and 100 v was used as a standard voltmeter (V_2). The switching of ranges was made by means of switch S_3.

Normally the voltmeter is connected to the secondary winding of transformer T3. When the magnetic starter MS_5 is operated (in the 35 kv circuit) relay R_2 disconnects the voltmeter from this transformer and connects it to transformer T1.

The operation of the remaining components of the circuit is obvious from the diagram. In order to facilitate the work of the tester, tables have been calculated which give the permissible deviations in the standard voltmeter readings for each division of the instrument under test according to its grade.

The calculations were carried out by means of the formula:

$$\alpha = \frac{u_n}{K_u C_u \left(1 - \frac{f_u}{100}\right)} - \Delta\alpha,$$

where α is the reading of the standard voltmeter in divisions, u_b is the voltage on the high side of the transformer (the point on the kilovoltmeter scale which is being checked), K_u is the nominal transformation ratio of the transformer, C_u is the value of the standard voltmeter division, f_u is the error in the transformation ratio, $\Delta\alpha$ is the correction in divisions for the standard voltmeter.

Above formula was obtained by a transformation of a similar formula given in instruction 184-54 of the Committee of Standards, Measures and Measuring Instruments.

Since transformer NOM-35 was checked in the step-up connection its errors were determined for a transformation ratio of (35,000/100). In the above formula, however, a reciprocal of this value is used and hence the error obtained must be taken with a reversed sign.

Checking instruments up to 10 kv dc. For this measurement a simple half-wave rectifier diode T_1 with an RC filter is used (see figure). In order to simplify the circuit the anode of the diode is fed from the high voltage winding of the same transformer T2, which is used in the ac circuit. Thus the entire connecting and adjusting circuit remains the same as for the 10 kv ac case (MS_4, AT3, AT4, T_6 and T_2). For dc working the heater of the diode is connected and the standard ac voltmeter disconnected by means of the double throw switch S_2.

A multi-range moving coil grade 0.5 voltmeter (V_3) is used as a standard dc meter, with the range switch S_4.

Electric strength of the insulation tests for instruments can be carried out either with automatic control of the voltage building up speed (up to 2 kv) and automatic test duration (of 1 minute) or with manual control of both quantities (up to 2 kv).

The instrument transformer T4 (NOM-6, 100/2, 100 v, 240 w) is used (similarly to the 35 kv circuit) both for stepping-up the voltage and measuring purposes. Such a use of the transformer, considering its power, is permissible in the circuit, although nominally its power (240 w) is a little smaller than the nominally permissible

power (250 w) for testing the insulation of instruments.

The insulation strength testing circuit is switched in by means of switch S_1. When this switch is thrown to the "manual control" position (left hand side in the circuit) the supply voltage is fed to autotransformer AT2 and then on to transformers T7 and T4. The slide of AT2 is connected through a reduction gear to the axle of the three-phase induction motor M. In the "automatic control" position switch S_1 through the magnetic starter MS_1 connects the supply to the motor. The speed of the motor and the reduction gear are selected in such a manner that the rate of voltage rise is approximately 100 v per second.

For the required test duration (1 minute) an electromechanical time relay TR is used.

The timely connection and disconnection of the time relay, the control of the magnetic starters MS_1 and MS_2, which in turn connect the motor M for a forward or reverse movement, is carried out by means of wafer contacts K_1, K_2 and K_3. The latter are actuated by a special disc ganged with the autotransformer slide AT2.

If the insulation of the instrument under test breaks down the overload current relay RM1 disconnects the voltage from transformer T4 by means of the intermediate relay R_5 and lights the signalling lamp L_5.

If the insulation strength has to be measured at a voltage higher than 2 kv the 10 kv ac circuit should be used.

The equipment is supplied with overload protection, light and bell signalling and safety interlocking.

The over-all dimensions of the set are 1.5 × 1.05 × 2.7 m and the approximate weight 500 kg.

The welded body of the equipment is grounded. The covering is made of sheet duralumin. All the controls are placed on the front vertical panel.

SUMMARY

This equipment provides completely satisfactory testing, by the comparison method of measuring instruments, up to 35 kv ac and 10 kv dc it can also be used for insulation strength testing.

The equipment is simple in construction and easy to use. The number of operations required for preparing the equipment for testing and during testing has been reduced to a minimum.

The use of simple automation provides a strict application of the specified conditions for insulation strength testing.

The equipment can be used in industrial measuring laboratories.

NEGATIVE LOSS ANGLE OF A THREE-TERMINAL CAPACITOR

M. A. Bykov

The principles involved in the construction and use of three-terminal capacitors, which have practically no loss (loss angle < $1 \cdot 10^{-5}$), have been dealt with extensively in the past (see, for instance [1].

The peculiarity of a three-terminal capacitor consists in the fixing, by means of a solid dielectric, of the two measuring plates on a base which also serves as a screen (the third electrode). In such a capacitor the direct capacity between the two measuring plates has an air dielectric and there are no direct admittances between them through the solid dielectric.

When the capacitor is used, for instance, in one of the arms of a bridge circuit, one of its measuring electrodes is connected to the zero potential point of the circuit, the other measuring electrode to the appropriate supply point of the bridge and the third electrode, the combined body and screen, to the auxiliary device which provides it with a potential equal to that of the zero diagonal of the bridge.

Under these conditions capacities C_{1S} and C_{2S}, which have losses in their solid dielectric, are not connected in any of the arms of the bridge and it is only the direct capacity between the measuring plates C_{12}, which has an air dielectric and is practically free of loss, that is connected across one of the bridge arms.

If the same capacitor is used in a two-terminal connection (when, for instance, its screen S is connected to its first plate) its "loss-free" capacity C_{12} will have the partial capacity C_{2S} in parallel with it and the combined capacity will have certain losses.

When testing, however, new type three-terminal variable air capacitors in a three-terminal connection (capacitors R-512, developed by the Kiev "Tochélectroptibor" plant) it was found that three of the four capacitors tested had a considerable negative loss angle (up to -25 to $-100 \cdot 10^{-5}$),* and the fourth had a considerable positive loss angle which was larger than its angle in a two-terminal connection (and approximately equal to the loss angle of the three first capacitors in a two-terminal connection). It would appear, however, that from the above-mentioned description of a three-terminal capacitor it is impossible to deduce such loss angles.

In order to clarify this point it is necessary to remember that in constructing the above-mentioned three-terminal capacitor picture it was tacitly assumed that its three partial capacities C_{12}, C_{1S} and C_{2S}, which form a triangle of capacities, were independent from each other and formed by completely separate electric fields; however if the construction of the capacitor is not completely right this may not be true and then the formation of partial capacities in the capacitor will be different.

Let us assume that three electrodes 1, 2 and 3 are placed on the periphery of a common space (Fig. 1a) which is filled mainly by air, but which has somewhere inside it a solid dielectric SD which has certain losses.

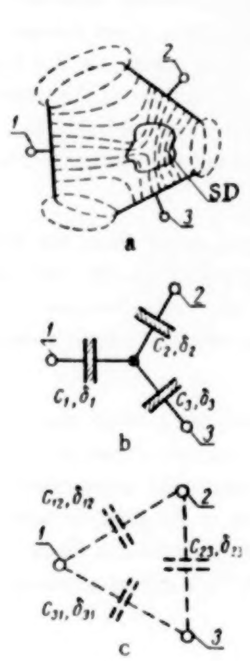


Fig. 1.

On the basis of the electric field diagram (Fig. 1a), which was drawn on the assumption that the dielectric constant of the solid dielectric was considerably greater than that of air, it is possible to represent the mutual relations between the electrodes 1, 2, and 3 by an equivalent circuit in the form of three partial star connected capacities C_1, C_2 and C_3 (Fig. 1b). Moreover, in the general case not one of these capacities will be "pure" and without losses, and each one of them will have its loss angle δ_1, δ_2 and δ_3.

The "star" connected capacitors C_1, C_2 and C_3 (with their losses) can be replaced by an equivalent delta circuit consisting of capacitors C_{12}, C_{23} and C_{31} with corresponding equivalent (effective) losses δ_{12}, δ_{23} and δ_{31} (Fig. 1c).

Having made certain analytical calculations it is possible to arrive at the following expression for δ_{12}.**

$$\delta_{12}=\frac{C_1\delta_2+C_2\delta_1+C_3(\delta_1+\delta_2)-C_3\delta_3}{C_1+C_2+C_3}.$$

If $C_3\delta_3 > C_1\delta_2 + C_2\delta_1 + C_3(\delta_1 + \delta_2)$, then with positive values of the loss angles δ_1, δ_2 and δ_3 the value of δ_{12} becomes negative.

The same will occur if the values of C_1, C_2 and C_3 are of the same order of $\delta_3 >> \delta_1$ and $\delta_3 >> \delta_2$.

On the other hand with very small but differing values of δ_1 and δ_2 and with changing ratios between capacitire C_1 and C_2 the resultant value of δ_{12} can also very considerably assuming both negative (with a large δ_3) and large positive values.

All these effects will take place in an actual three-terminal capacitor and the expression given above for δ_{12} will hold for a three-terminal connection of such a capacitor if the indices "3" are replaced by "S".

* As long ago as 1938 Astin (USA National Bureau of Standards) reported (Physical Review, v. 55, No. 6, March 15, 1939) that he discovered a negative loss angle of the order of $-7 \cdot 10^{-5}$ in well-screened three-terminal capacitors at 60 cps. Astin and Curtis attempted to explain this phenomenon by assuming a certain source of energy in the screen electrode circuit. The authors noted that they had no experimental confirmation of their assumption. It would appear that this assumption is close to the idea expressed in this article.

** An expression for δ_{23} and δ_{31} can easily be obtained from the above expression by a change-over of subscripts; expressions for C_{23} and C_{31} in this case are of no interest.

As far as the R-512 capacitors are concerned their above mentioned negative or high positive loss angles (in a three-terminal connection) are due to a certain defect in them.

Figure 2a shows schematically a part of the R-512 capacitor, namely the upper end of its rotor,* where plates 1 are fixed to the rotor which forms part of the capacitor screen S, by means of insulated washers and bushes made of a solid dielectric – micalex. The uppermost stationary plate 2 is also near their place. It will be seen from Fig. 2a that in this place the mutual position of the three electrodes and the solid dielectric corresponds to Fig. 1a. Micalex has a very large loss angle amounting to 0.05-0.07 so that capacity C_3 (Fig. 1b) has also a very large loss angle δ_3 in this inductance. As far as the capacities C_1 and C_2 are concerned they can also have large loss angles δ_1 and δ_2 although considerably smaller than δ_3 since they are only partially due to the larger loss angle of micalex. The relationship between capacities C_1 and C_2 in the parts where they are formed through the electric field in the micalex bush and the values of the corresponding loss angles δ_1 and δ_2 depend on the position of plate 2 with respect to the protruding end of the micalex bush.

When two of the R-512 capacitors one with a negative and the other with a large positive loss angle were opened up it was found that in one of them the end plate 2 was closer to the lower edge of the bush and in the other to the upper edge.

In considering the question of the relationship between capacities C_S, C_1 and C_2 and the corresponding loss angles $\delta_S (\delta_3)$, δ_1 and δ_2 as shown in Fig. 1b but relative to Fig. 2a, only the interrelated capacities which were formed in the space under the effect of all the three electrodes were taken into account, and closely represented with respect to their physical effect by the star connection of the three partial capacities.

The capacitor also has other completely different partial capacities which are subjected to the effect of practically only one pair of electrodes, for instance, the capacity between all the moving plates 1 and the spindle of the rotor S, formed across the micalex bush which separates them, or the capacity between plates 1 and 2 formed in the narrow "purely air gaps" between the plates away from the rotor spindle and the outer screen of the capacitor. In the formation of these capacities a third electrode does not take part and their operation must naturally be represented by a delta equivalent circuit. This is in complete agreement with the "classical" representations of a three-terminal capacitor described at the beginning of this article.

In the R-512 capacitors all above abnormal effects were accordingly particularly noticeable when the direct capacity C_{12} formed by electrodes 1 and 2 in a purely air space was at its minimum and very small and when the capacities formed in the spaces with the solid dielectric under the effect of all the three electrodes became relatively large. And vice-versa when the maximum capacity of the R-512 capacitor was used all above abnormalities were hardly noticeable.

All these abnormalities were completely eliminated in one of these capacitors which had a large negative loss angle by adding to it two brass screening caps: one at the top end of the rotor in the manner shown in Fig. 2b and the other similarly at the bottom end. The loss angle of this capacitor in a three-terminal connection became smaller than $1 \cdot 10^{-5}$ since all the solid dielectric of the capacitor became located in the zone of action of one pair of electrodes only (1-S) and not all the three electrodes. Spaces under the effect of all the three electrodes 1, 2 and S remained in the capacitor, of course, but since they became "purely" air spaces which do not contain any solid dielectric they stopped producing any abnormal effects.

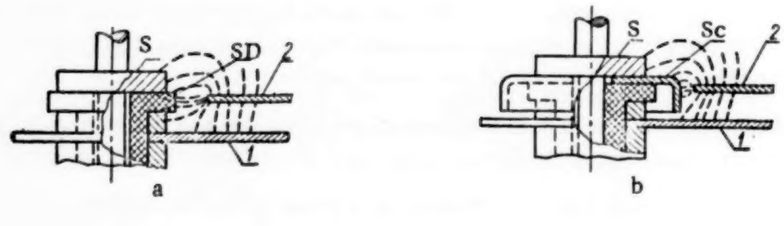


Fig. 2.

* A similar condition prevails also at the lower end of the rotor.

SUMMARY

1. Both theoretically and practically it is quite possible to obtain a capacitor with an effective negative loss angle or without a loss angle by means of three actual capacitors with actual losses connected according to the circuit shown in Fig. 1b, although in practice such conditions arise only in very rare special cases.

2. When a three-terminal loss-free capacitor is designed it is necessary to adhere to the following rules.

All the details of a three-terminal capacitor which are made of a solid dielectric should be placed in spaces where they are affected by only two pairs of electrodes: "the first measuring electrode and the screen" or "the second measuring electrode and the screen" with a complete absence of the effect of a third electrode (the second measuring electrode in the first instance and the first measuring electrode in the second instance). The presence of a solid dielectric in the field between the first and second measuring electrodes is also, obviously, not permissible.

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[1] M. A. Bykov, "Loss-free air capacitors and an experience of their application" Proceedings of the MGIMIP issue 2, [in Russian] (Mashgiz, M., 1950).

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

ELECTRONIC FREQUENCY CONVERTERS FOR PRECISION MEASUREMENTS

V. K. Potekhin

Very stable frequencies of different nominal values are indispensable for series of accurate measurements. Thus in VNIIM it was necessary to obtain stable frequencies of 1016, (6); 1002, 73791 and 2160 cps. Direct reproduction of such frequencies in each separate case is connected with a number of technical difficulties and, therefore, it is practical to convert one highly stable (original) frequency into the required frequencies.

The converted frequencies generally differ from the original one by a factor less than unity. In what follows, we shall call these frequencies fractional.

Two methods of obtaining fractional frequencies can be distinguished:

1) electromechanical, consisting of frequency conversion by means of a motor-generator system, interconnected by a reductor having a fractional transmission ratio;

2) electronic, consisting of shifting, dividing and multiplying the original frequency [1].

In this paper the second method is being considered, which does not have the defects inherent in the mechanical system and, therefore, is preferable.

A single stage electronic converter makes possible the following forms of frequency conversion:

1) the division of frequency into an arbitrary integral number, not exceeding x; the value of x being chosen from the considerations of time stability and of the divider;

2) multiplication of frequency by an arbitrary integral number not exceeding y, where y is determined by the quality of the filter of the multiplier;

3) shifting of frequencies (summation and subtraction) in which one frequency does not exceed the other by more than z times, where z depends on the quality of the separating filter of the device.

We shall thus represent the required frequency f_x by an obvious relation

$$f_x = k f_{in}, \tag{1}$$

where k is the conversion coefficient and f_{in} is the initial frequency.

The analytical problem may be reduced to finding the sum (with the requirement that the number of terms n be small) of the form

$$f_x = \sum_{i=1}^{n} \frac{a_i f_{in}}{b_i}, \tag{2}$$

where

$$a_i = [2^{\nu}; 3^{\delta}; 5^{\gamma}; \ldots \ldots y^{\lambda}].$$
$$b_i = [2^{\alpha}; 3^{\beta}; 5^{\gamma}; \ldots \ldots x^{\varepsilon}].$$

$[\alpha, \beta, \gamma \ldots \delta \ldots \varepsilon]$ are nonnegative integral numbers.

$$\frac{a_{i+1}}{b_{i+1}} > \frac{a_i}{b_i} > z\frac{a_{i+1}}{b_{i+1}}. \tag{3}$$

The minimum solution is not obvious. An exact solution, without taking into account the requirement for minimum $\underline{n}$, is possible if

$$k = \frac{p}{q}, \tag{4}$$

where

$$q = [2^{\alpha} \cdot 3^{\beta} \cdot 5^{\gamma} \ . \ . \ . \ x^{\varepsilon}].$$

In that case the value of the product $p \cdot f_{in}$ may be obtained, e.g., by the method of summation of parts of the initial frequency which are integral multiples of numbers from 1 to 10.

TABLE 1

f_x, cps	1002,7379	1016,(6)	2164
f_{ucx}, kc	1000	1000	100
k	$\frac{3662422}{3652422} \cdot 10^{-3}$	$\frac{61}{60} \cdot 10^{-3}$	$\frac{541}{25} \cdot 10^{-2}$
k'	$\frac{42115}{42000} \cdot 10^{-3}$	–	$\frac{13}{6} \cdot 10^{-3}$
f'_x, cps	1002,7381	1016,(6)	2166,(6)

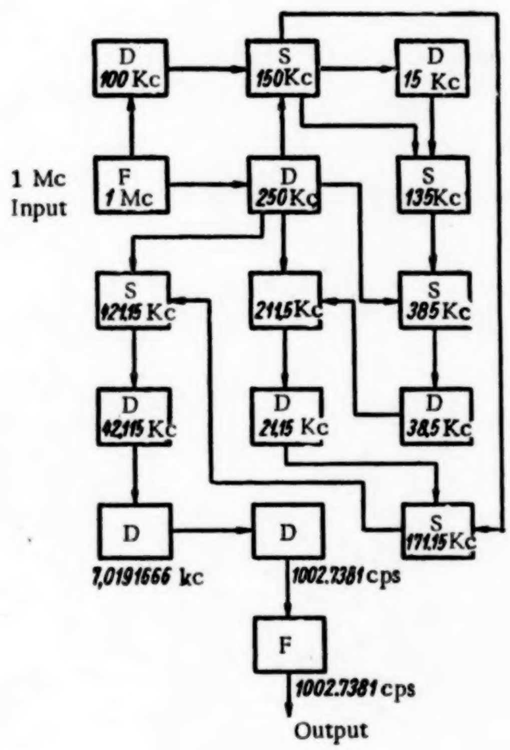

Fig. 1.

For example, let the required frequency be 610 kc with the initial frequency being 1 Mc:

$$610 = \frac{1000}{2} + \frac{1000}{2 \cdot 5} + \frac{1000}{2^2 \cdot 5^2} = 500 + (100 + 10).$$

In a case where the value of $\underline{q}$ is not observed, it is possible to find an approximate solution with a specified degree of accuracy, i.e., to determine

$$k' = \frac{p'}{q'} \simeq k.$$

By using the methods of the theory of numbers any number can be represented in the form of a series of approximate values.

In this case the most convenient form of approximation is of continued fractions [2, 3], since the requirement for minimum $\underline{n}$ can be better fulfilled that way.

Let $\underline{k}$ be given in the form (4) and let $\underline{q}$ not correspond to the condition of that formula.

We shall represent $\underline{q}$ in the form

$$q = c - d, \tag{5}$$

where $\underline{c}$ satisfies the condition (4) and is no more than $\underline{z}$ times greater than $\underline{d}$. In that case

$$k = \frac{p}{c-d} = \frac{p}{c}\left(\frac{1}{1-\dfrac{d}{c}}\right). \tag{6}$$

Expressing $\dfrac{1}{1-\dfrac{d}{c}}$ in the form of a series (an infinite diminishing geometrical progression)

we shall obtain for k an expression:

$$k=\frac{p}{c}\left(1+\frac{d}{c}+\frac{d^2}{c^2}+\ldots\right). \tag{7}$$

The required coefficient k may be obtained with a sufficient degree of accuracy by taking the required number of components in that sum. It is convenient to make use of that method when the values of c and d can be chosen so as to obtain sufficiently rapid convergence of the series, and at the same time satisfy the condition (3).

TABLE 2

s	1	2	3	4	5	6	7	8	9	10	11	12	13
p_s	2	3	8	11	52	115	282	397	679	1076	1755	8096	17949
q_s	1	1	3	4	19	42	103	145	248	393	641	2957	6555
q_{sk}	1	1	1.3	2^2	1·19	6·7	1·103	5·29	2^3·31	3·131	1·641	1·2957	5·5·19·23
f_s'	—	—	—	2.75	2.7368	2.7381	2.73786	2.73793	2.73790	2.73791	2.73909	2.73791	2.737901

Remarks: s) number of the appropriate fraction; p_s) the numerator of the fraction; q_s) the denominator of the fraction; q_{sk}) the denominator represented in a canonic form; f_s') the frequency corresponding to the conversion coefficient $\frac{p_s}{q_s}$.

In Table 1 series of values of fractional frequencies are shown and also corresponding to them, initial frequencies, the values of k, calculated k' and the values of the frequencies f_x' corresponding to k'.

The installation for obtaining the frequency of 1002.7381 cps was intended for continuous use in Time Laboratory as sidereal time. The determination of the unknown coefficient k' in the given case can be obtained by expanding a part of that coefficient, namely the number 2.73791, into a continued fraction.

The results of the expansion are shown in Table 2.

As seen from the expansion, fraction S = 6 corresponds to the condition (4).

Thus the conversion coefficient for obtaining the frequency 2.7381 cps is $\frac{P_6}{q_6} = \frac{115}{42} \cdot 10^{-6}$ and for the required frequency 1002.7381 cps $k' = \frac{42115}{42000} \cdot 10^{-3}$.

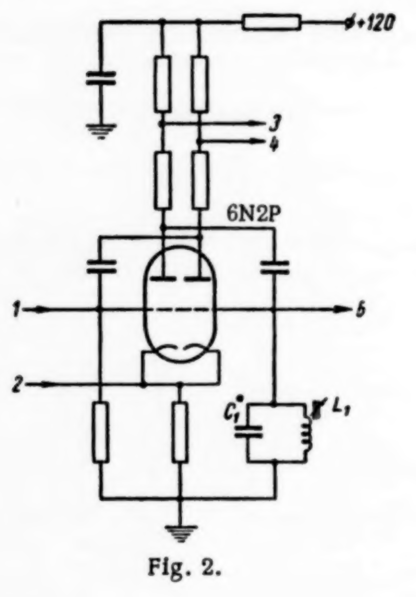

Fig. 2.

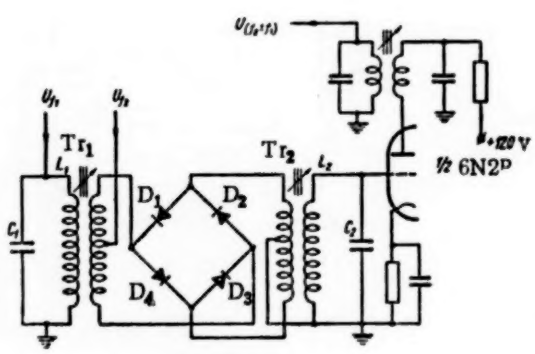

Fig. 3.

In working out the block diagram (Fig. 1) the convenience of making the fundamental frequency conversions on sufficiently high frequencies was taken into consideration. In a number of cases, when the initial frequency was considerably higher than the required one, it was possible to avoid the use of multiplier stages (in the converters VNIIM they were not used). All converters consist of some type of frequency-dividing and frequency-shifting stages. For the divider stage a synchronized multivibrator, with the tube 6N2P, was used with a resonating circuit connected to the grid circuit of one of the triodes. The value of $\underline{x}$ was chosen to be 11 [4].

The general circuit of the divider is shown in Fig. 2. The magnitudes of resistors and capacitors in that circuit determining the division coefficient of the stage, equal 10 at the synchronizing voltage frequency of 1 Mc.

The free running frequency of such a multivibrator, determined by the parameters of the circuit L_1 and C_1 [5], should be somewhat lower than its frequency in the synchronization region. The synchronizing voltage, having magnitude of the order of 1.5-2 v, may be fed into the grid of one of the triodes 1, if it is necessary to have a high input impedance, or into the cathode circuit 2, if the preceding stage is designed for a low impedance load.

The voltage, at a reduced frequency, may be taken off the potential dividers 3, 4 to the plates of the multivibrator tube, or off the resonant circuit 5, and fed into the following stages. In the latter case the voltage will have a sinusoidal form.

In the frequency-shifting stage a balanced ring modulator is used [6], the basic features of which are the presence of the sum and the difference of input frequencies in its output spectrum, and the absence of frequencies which are being shifted, which makes it easy to filter out the wanted components. Taking that into account, the value of $\underline{z}$ was chosen to be 20. The general circuit of the frequency-shifting stage is shown in Fig. 3. The frequency-shifting circuit works on germanium diodes, Type D2G. The transformers Tr1 and Tr2 are designed to match the loads and are assembled on shell type cores SB. The winding L_1 is tuned to the frequency f_1 by means of C_1, the winding L_2 by means of C_2 is tuned to the wanted component $f_1 + f_2$ or $f_2 - f_1$. The voltage $U_{f_1} \simeq 1$ v, $U_{f_2} \simeq 10$ v. As a separating stage, a resonant amplifier with the tube 6N2P and a resonant circuit in the plate, was used [7].

The sidereal clocks constructed in VNIIM contained 15 electronic tubes and 24 germanium diodes. Their introduction allowed a simplification of the processing of the astronomical observation of the Time Service, their use for the comparison of clocks run according to sidereal time, and also relay the sidereal frequency in Pulkovski Observatory and in the Observatory of the University of Leningrad.

The frequency 1016, (6) cps was intended for the reception of rhythmic time signals for a chronoscope according to the method of continuous reading. The constructed frequency-changing apparatus allowed for considerable simplification of comparisons in the Time Service of VNIIM.

The frequency of 2164 cps was obtained in the Magnetic Measurements Laboratory and was intended for the accurate measurements of the frequency of the free-precess proton precession in the earth's magnetic field.

The described method makes it possible to obtain practically any fractional frequency, which may find applications in other domains of measurements.

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V. G. Zhelnov

The proposed circuit is a modernized version of a low frequency band pass filter for the suppression of higher harmonics, described earlier by the author [1]. In the original version of that circuit the frequency change of an LC circuit was accomplished by means of changing the equivalent inductance, which made it possible to obtain a frequency coverage coefficient of 3.

The coverage coefficient may be increased to the value of 10, if the ordinary capacitance in the circuit is replaced by a regulated capacitance circuit, analogous to the circuit with regulated inductance (Fig. 1). It is easy to show that the value of the equivalent capacitance at the input of that circuit can be expressed in the following form:

$$C_e = C\frac{1}{1+SR_1},$$

where C is the value of the capacitance connected at the input of the cathode follower, S in the mutual conductance of the tube, R_1 is the resistance of the cathode follower load.

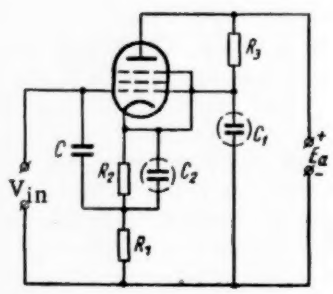

Fig. 1.

With the mutual conductance of the tube S = 9 ma/v (for the tube Type 6Zh4) and change of the resistance R_1 from 0 to 1 kohm, C_e changes by a factor of 10.

The full schematic of the filter with regulated capacitance and inductance is shown in Fig. 2. By moving the slider of the variable resistance R_1 from the left extreme position to the right produces a resistance change in the load of the regulated capacitance stage from 0 to 1 kohm and at the same time, from 1 kohm to 0 in the regulated inductance stage. That, in turn, produces the change of the product L_eC_e by a factor of 100, which corresponds to a tenfold change in the frequency of the circuit. Thus, at the magnitudes of L = 1.5 h and C = 0.005 μf the frequency of the filter changes in the range of 550-5500 cps.

In that way, the improved filter circuit as distinct from the one described earlier [1], makes it possible to cover a given band of frequencies in half the number of sub-bands.

It should be added, that when necessary, the sub-band coverage coefficient should be increased by means of changing tubes for ones having higher mutual conductance, and not by increasing R_1, since the latter leads to deterioration of the circuit Q, i.e., to a reduction of attenuation of higher harmonics.

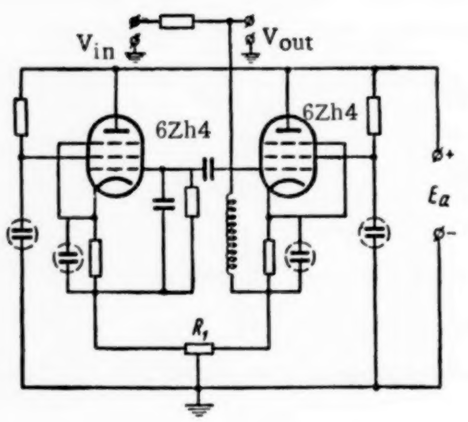

Fig. 2.

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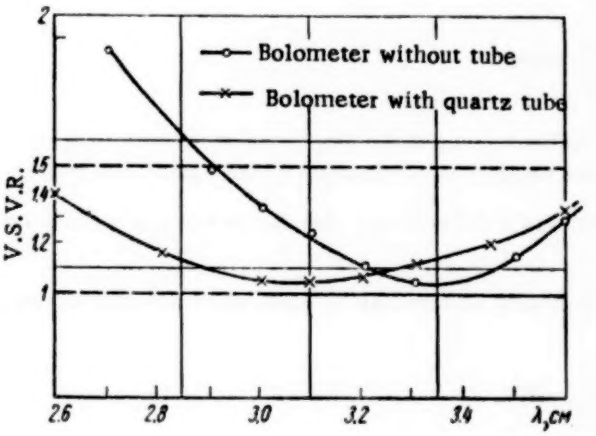
SIMPLE METHOD OF WIDENING THE WORKING FREQUENCY BAND OF FILM BOLOMETERS IN THE SUPER-HIGH FREQUENCY RANGE

V. A. Yugov

Film bolometers for power measurements at super-high frequencies find ever increasing applications [1, 2, 3].

The bandwidth, however, of an untuned bolometer head without a band widening system is insufficient for band measurements.



As a result of investigations of different band-widening methods we have proposed a method of band-widening by means of quartz tubes.*

The introduction of a quartz tube into the waveguide may be represented as connection of a certain capacitance in parallel to the film bolometer.

The bolometer element is situated inside the quartz tube, so that, in addition to its band-widening function, the quartz tube may serve a number of constructive purposes.

The experiments, which were carried out, have shown that the quartz tube having an optimum diameter and wall thickness produces a widening of the working-frequency band of a film bolometer of 20-25% of the original value of its bandwidth. The graph shows the result of measurements in the 2.6-3.6 cm band.

The preliminary experiments have shown that the efficiency of bolometric heads, having film bolometers in quartz tubes, is the same as that without quartz tubes (the accuracy of efficiency determination ±5%).

We are continuing, at present, a detailed investigation of the applications of quartz and other dielectric tubes for widening the working frequency bands of film bolometers.

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*A number of experiments was carried out by junior scientific assistant Yu. A. Durasov.

ON A METHOD OF MODULATION METER CHECKING OF THE STANDARD SIGNAL GENERATOR TYPE GSS-6

V. Ya. Volodarskii and N. U. Kokhanovskii

The checking of the modulation meter of the Standard Signal Generator, Type GSS-6 was found to be difficult because of the absence of commercial types of modulation meters for measurements of the modulation depth coefficients of low power signals. Instruments, which are recommended for that purpose, are not mass produced, and their construction in testing units presents understandable difficulties.

It can be seen from the schematic of GSS-6 that the determination of the modulation coefficient is made by separate measurement of the carrier level and of the amplitude of the modulated signal envelope, which are indicated by two vacuum tube voltmeters. The modulation coefficient is determined by the ratio of the readings of these voltmeters, i.e.,

$$M\% = \frac{u_{\sim}}{u_0} 100\%, \tag{1}$$

where u_0 is the carrier level, determined from the carrier voltmeter; $u_{\sim}$ is the amplitude of the envelope separated by the detector of the carrier voltmeter and measured by the vacuum tube voltmeter of the modulation meter.

For a definite carrier level (1 v) the modulation meter scale is calibrated directly in terms of modulation coefficient percentage.

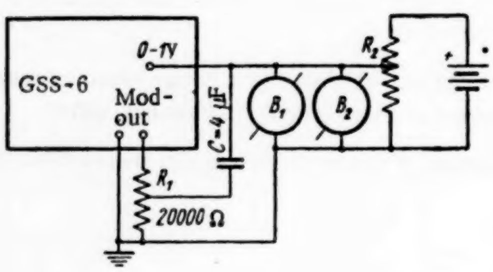
In order to check the modulation meter of GSS-6 a pulsating voltage can be used, which changes according to the envelope of the high frequency signal:

$$U = e_0 + u_{ac}\cos\Omega t, \tag{2}$$

where e_0 is the constant component of the pulsating voltage, which duplicates the carrier level of the high frequency signal; v_{ac} is the amplitude of the acoustic frequency voltage, duplicating the modulating voltage of the high frequency signal.

To check the modulation meter, the pulsating voltage is fed to the input "0-1 v" of the instrument GSS-6, i.e., to the anode of the detector of the carrier voltmeter.

As a source of the acoustic frequency, the modulator of the GSS-6 under test can be used.



The schematic of the testing arrangement is shown in the figure. The method of testing is as follows.

The band switch of the Generator GSS-6 is put in the neutral position and the pointer of the carrier voltmeter is brought to zero with the control "Carrier zero adjust." The "Microvolts" control knob should be set in the extreme clockwise position. Toggle switch "Int. mod. – Ext. mod." set to the position "Int. mod.," and the control "% modulation" in the extreme anticlockwise position.

A constant voltage of the order of 1 v is fed in the input "0-1 v," and the voltage from the modulator of the tested GSS-6 is fed as shown in the figure.

The pointer of the carrier voltmeter is set to "1 μv" with the variable resistor R_2, and the indication e_0 of the dc voltmeter B_2 is noted.

The pointer of the tested modulation meter is set to the scale indications by means of the variable resistance R_1, and the indications V_{ac} of the ac voltmeter B_1, are noted.

The "modulation coefficient" of the pulsating voltage is calculated from:

$$M\% = \frac{\sqrt{2}u_{ac}}{e_0} 100\%. \tag{3}$$

The error of the tested modulation meter is determined from the formula

$$\Delta M\% = M_{nom} - M, \tag{4}$$

where M_{nom} is the modulation coefficient read from the scale of the modulation meter under test; M is the "modulation coefficient" of the pulsating voltage determined from (3).

The error of the modulation meter should not exceed ±5% for $M \leq 50\%$ and ±10% of the measured value for $50\% \leq M \leq 100\%$.

RADIATION MEASUREMENTS

DETERMINING IONIZATION WORK DONE IN AIR BY GAMMA-RADIATIONS Co^{60}

K. K. Aglintsev, G. P. Ostromukhova and E. A. Khol'nova

The work done by ionizations is the basic physical constant in the sphere of x-ray measurements and it represents the ratio between the energy of the ionizing radiations absorbed in a gas and the number of ion pairs produced by it. It is expressed as the quotient of the energy W_a absorbed by a certain volume of gas to the number N of ions formed by this energy:

$$\varepsilon = \frac{W_a}{N} \tag{1}$$

Thus energy ϵ represents the mean energy required to form an ion pair in the gas.

Changes in the relation between the energy spent in ionizing the gas and in nonionizing losses of radiation at different wave-lengths must produce changes in the amount of ionization work done.

To date there are no precise experimental data giving the value of ionization work done in the sphere of hard gamma-radiations. One can only mention a note [1] in which the value of ionization work done is reported for gamma-radiations Co^{60} as being equal to 34.2 ev.

We conducted an experimental investigation of the ionization work in air for gamma-radiations Co^{60}. The value of ionization work done was measured by means of a preparation in a normal ionization chamber [2, 3] which determined the number of ion pairs and a gamma-calorimeter which gave the value of the absolute activity of the same preparation.

The normal ionization chamber worked at a higher than normal air pressure of 9-10 A_s, which ensured a complete utilization of the ionizing properties of the electrons. By measuring the dosage rate P in r/sec at distance R from the preparation it is easily possible to obtain the number of ion pairs formed. A dosage rate of 1 r/sec corresponds to the formation of 1 cm^3 of air under normal conditions of $2.08 \cdot 10^9$ ion pairs and dosage rate of P r/sec to $P \cdot 2.08 \cdot 10^9$ ion pairs in 1 cm^3 of air.

The gamma-radiation energy absorbed under normal conditions in 1 cm^3 of air was determined from the formula:

$$W_a = \frac{[h\nu_1(\tau + \sigma_\beta)_1 + h\nu_2(\tau + \sigma_\beta)_2]}{4\pi} Af, \tag{2}$$

where $h\nu$ is the energy of gamma-ray quanta; $(\tau + \sigma_\beta)$ is the sum of the linear coefficients of photoelectric absorption and the absorption due to scattering in air, whose numerical values were obtained from tables in [4]; A is the absolute activity of the preparation; f is a correction for self-absorption in the preparation of a cylindrical shape in the direction of its axis.

The absolute activity of preparation Co^{60} was determined by means of lead spherical gamma-calorimeters of a static type [3, 5] which absorbed 85% of the Co^{60} preparation gamma-radiations.

The mean value of the ionization work done, obtained from measurements of four different Co^{60} preparations, was found to equal 33.7 ±1.5 ev.

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* See English translation.

INFORMATION

THE SECOND SESSION OF THE INTERNATIONAL COMMITTEE ON LEGISLATIVE METROLOGY

The International Organization of Legislative Metrology is an intergovernmental agency whose object is to solve on an international scale technical and administrative problems which arise in connection with the use of measuring instruments covered by official rules. In its activity the organization deals with national state agencies for measures and measuring instruments.

The 2nd session of the International Committee of Legislative Metrology was held on October 6-8, 1958 in Paris. Representatives from 22 countries of the 28 which adhere to the convention took part in the session.

The committee discussed questions regarding the membership of the organization. It was stated that the French Government had received 20 ratifications from member states of their adherences to the inaugural convention of the International Organization of Legislative Metrology and that parliaments of three others countries were discussing the questions.

When the list of member states was examined a query was raised. Although the GDR has announced its adherence to the convention in October 1956; had taken part in a joint German delegation to the 1st General Conference of Legislative Metrology, is acting as a secretary-rapporteur on the question of "Medical Thermometers," and is collaborating in several other secretariats, the keeper of the convention, France has not, however, as yet informed other members of the organizations of the adherence of the GDR to the convention.

In order to extend the activity of the organization and increase the number of member states the Committee decided to advise the delegates of various countries to do everything in their power to popularize the organization in all the countries of the world.

The Committee examined the financial position of the organization for the period from October 1956 to December 1958. The balance sheet for that period presented in the International Bureau Director's report was approved by the Committee.

The Director of the Bureau presented to the Committee the budget for 1959-1960 which envisages the extensions of the organization's activity and a larger personnel. The committee accepted the proposed budget.

The Committee was informed of the relations between the bureau and other international organizations. A mutual recognition agreement between the IOLM and UNESCO was approved. This document notes that the UN recognizes the IOLM as an international agency for legislative metrology.

As regards the relation of the IOLM with other international organizations whose activity is related to metrology, the Committee was pleased to note that these relations were very close and included exchange of documents and observations. The Committee expressed its desire that these relations should be improved still further in the future.

The Committee examined the proposed questionnaire on the inspection of measuring instruments in various countries and approved it in principle. It was decided that each member of the Committee should express his opinion on the drafting by the Bureau of a sample questionnaire to be sent to all the member states and eventually distributed in all the countries of the world.

The International Bureau submitted to the Committee a preliminary draft report on the establishment of a legislative metrological service. For the working out of this question the Committee has established a secretariat, whose working party consists of all the member states of the IOLM. It was decided to request all the member

states to express their opinions on the question, so that they could be considered in drafting the final document which will be eventually adopted on an international scale. It was decided to publish once a quarter an official bulletin in French entitled "International Bulletin of Legislative Metrology."

The Committee examined the problem of an international system of units and adopted unanimously the following resolution:

"The International Committee of Legislative Metrology at its plenary session on October 7, 1958, held in Paris, declares its adherence to the resolution of the International Committee of Weights and Measures, on the establishment of an international system of measuring units (SI).

The basic units of this system include: meter—kilogram—second—ampere—degree Kelvin—candle.

The Committee recommends member states to adopt this system of measuring units by legislation."

The Committee approved certain measures of reorganization of the IOLM. Three categories of membership were established: member states, corresponding states, and corresponding organizations. It was decided that the number of Committee members would not be limited, it would include a representative from each member state. Finally the Committee approved the establishment of a Council of the Committee's Presidium for helping the President in his work.

Great attention was paid at the Committee's session to the work of member states as secretary-rapporteurs or collaborators in working out different problems of legislative metrology.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

WEIGHT-MEASURING EQUIPMENT REPAIRS IN AGRICULTURE*

V. V. Petropavlovskii

S. I. Gauzner is right in stating in his article that the repair of the weight-measuring equipment at the local industry plants is badly done, that the equipment of the weight-measuring instrument repair shops is unsatisfactory and that nobody is interested in the training of specialists in the production and repair of scales and weights. His arguments, however, for organizing the repairs of weighing instruments in (TRCs) technical repair centers require serious critical consideration.

As a matter of fact, if the weighing equipment repair crews organized as proposed by S. I. Gauzner in the TRCs are charged with repairing the equipment used only in agriculture proper, they will not have enough work to do; if on the other hand they are charged with repairing all the weight-measuring equipment in rural districts, including that used by the Tsentrosoyuz,** whose equipment amounts to at least 50% of the total used in the district, there will be no improvement compared with the existing method of repairs.

In fact, the TRC weighing equipment repair crews would have to be organized from scratch. It is doubtful whether the supply of standard and reference instruments to the TRCs as suggested by S. I. Gauzner would produce any saving. It is also difficult to imagine that the TRCs which have no experience in repairing weighing equipment or the required personnel, would improve the quality of repairs.

Moreover, most of the TRC customers are outside organizations, hence the former tendency of local industry plants of charging high prices for repairs and repairing badly may remain.

In this connection it seems inadvisable to stop the work of badly-functioning weighing-equipment repair organizations of the local industry and replace them with similar organizations in the TRCs.

It is obviously possible to organize, in certain cases, weighing equipment repair crews not only in TRCs but even in collective farms as it has been done in the Krasnodar region, but the main attention should be paid to the improvement of the work of local industry plants.

It is necessary in the first instance to organize in each region (territory) special weighing equipment plants with town and country branches, for whom the repair of scales and weights would be the main and not subsidiary task.

It is necessary to discontinue the nefarious habit of organizing weighing equipment repair shops in furniture woodworking plants, district industrial combines etc., as it is done in the Tambov region and even in Moscow. The point is that the administration of these establishments regards the weighing equipment repairs shops as an extra burden which it would gladly avoid and certainly it does not even contemplate making repairs more efficient, of better quality, and less costly.

Simultaneously it is high time to organize an efficient supply of reference and measuring instruments, spare parts, gauges and materials for the weighing equipment repair shops, and to train specialists in this work.

When discussing savings in the maintenance of the measuring equipment it is worth noting that the reduction of the cost of repairs is not the only source of economy of state funds. In order to decrease this expenditure which according to S. I. Gauzner amounts in agriculture alone to the enormous sum of 50 million roubles per annum it is necessary to:

*By way of discussion of S. I. Gauzner's article "Organization of Weight-Measuring Equipment Repairs in Technical Repair Centers" (see "Measurement Techniques," No. 4, 1958).

**Trans. note: Tsentrosoyuz = Central Cooperative Society.

a) improve the working quality of scales and weights.

b) make the conditions of their application and preservation more efficient.

c) improve the organization of the weighing equipment repairs.

There is every reason to believe that the working quality of the weighing equipment has not improved in the last few years. In certain cases it has actually deteriorated. Some of the scale manufacturing plants introduce various simplifications in their construction. This,no doubt,makes their production less expensive but it also ruins their quality. This was the case with the pharmaceutical balances made by the Tulino metalwork plant, which "rationalized" their production to such an extent that the balances became unstable and had to be withdrawn from production. To date there are no mass-produced scales or weights with anti-corrosive properties, although the greater part of weights and scales particularly in country districts has to be prematurely repaired due to corrosion.

The handling of the weighing equipment is also very bad. In this respect hardly anything is being done; there are no posters, leaflets, no educational films, no instruction in schools, at seminars or courses etc.

As far as the improvement of the equipment repairs is concerned, the existing system of individual repairs is obviously obsolete. It is necessary to change over immediately to the exchange method of repairs where the owner of the weighing equipment is supplied with scales and weights which are repaired and state-certified in place of these he hands over for repairs, with the exception, of course, of heavy stationary scales which will have to be repaired on the spot. The exchange method of repairs has undoubted advantages. Its application on an all-union scale would provide great economy not only in transportation but also in time used by people who carry out the inspection.

Finally a new form of weighing equipment utilization, its hire to the customers, should be introduced. There were many organizations which require a large number of scales and weights only for a short time (for instance collective farms, stocking organizations, etc.). Why should they tie up large sums of money in purchasing weighing equipment which for the greater part of the year is not being used, deteriorates through bad maintenance, and requires premature repairs? It is too soon to decide who should hire the scales and weights since this question is still under discussion. It is possible that this task will have to be entrusted to the TRCs which will, according to the available information, hire agricultural implements.

IMPROVING THE ORGANIZATION OF WEIGHT-MEASURING EQUIPMENT REPAIRS

S. I. Gauzner's article* on changing the organization of weighing equipment repairs provoked lively response from the readers of our journal. Despite the difference in the points of view expressed, all the contributors unanimously agree on the urgency and importance of the problems dealt with in the article.

The director of the Bryansk weighing equipment repair plant, com. Novikov, writes that the weighing equipment repair plants, in the majority of cases belonging to the regional local industry administrations, have inadequate equipment and are in fact semi-handicraft workshops. It is completely out of the question to be able to improve the quality and decrease the cost of repairs under these conditions. All these circumstances narrow the sphere of operation of these organizations: they are unable to carry out many of the repairs, so that expensive instruments with small defects have to be scrapped.

The idea of passing the repair of the weighing equipment of the collective and state farms to the Technical Repair Centers (TRCs) as suggested by S. I. Gauzner is not new. Previously it was suggested to entrust the Machine and Tractor Stations with such repairs, but this measure was never put into effect owing to numerous difficulties, especially in technical material supplies and lack of personnel. A similar situation may arise if S. I. Gauzner's

* See "Measurement Techniques" No. 4, 1958.

suggestion is implemented, especially since he only dealt with a part of the problem, having omitted the fact that the weighing equipment of other organizations is repaired just as badly and expensively even in towns.

In his opinion states com. Novikov the solution of this problem important for the whole of the national economy is to be sought in the strengthening of the existing repair organizations both materially and technically instead of in the establishment of new repair workshops. Despite S. I. Gauzner's assertations, these establishments possess trained personnel. It is quite a different matter that the personnel which consists mainly of self-taught practical workers with a 20-25 years' experience of dealing with instruments is not being supplemented by youth. Therefore the raising of the question of training young specialists for the repair of measuring instruments is quite justified.

Moreover, a centralized supply of the weighing equipment repair establishments with spare parts, materials, instruments and, above all, with reference and measuring instruments should be organized.

The solution of all these problems should be the immediate concern of the Committee of Standards, Measures and Measuring Instruments and, in particular, of the State Inspection Laboratories for Measuring Instruments.

The head of the Kimr' branch of the Committee of Standards Measures and Measuring Instruments, com. Golikov, and chief state inspector of the branch, com. Kazanskii, write that S. I. Gauzner's suggestions of organizing the repair of weighing devices in Technical Repair Centers should be supported. The experience of organizing temporary branches in rural districts have shown the inadvisability of carrying equipment for checking or repairs long distances away. During transportation scales are often damaged or put completely out of commission. Moreover the repair of scales in temporary branches proceeds very slowly owing to the large number of them that have to be dealt with at the same time.

The weighing equipment repairing crews of the TRCs could not only repair but also rebuild faulty equipment. Although there is a shortage of scales in the collective farms, often one sees unused scales there, which were abandoned as a result of the breakage of the wooden parts. The TRCs should organize the repair of weighing equipment on the spot in the collective and state farms, which would improve the quality and reduce the cost of repairs. It is necessary to entrust the repairs to the TRCs by legislation so that their management should consider it their own business.

S. I. Gauzner is also right when he suggests opening in the Kalyazinsk Mechanical Technical School a department for training technicians in the repair of scales. This department formerly existed in the school, and still maintains a body of qualified teachers, along with standard instruments, laboratory equipment, and the workshops which they used in making measuring instruments.

At the same time it is necessary to train personnel with a secondary technical education for repairing other measuring instruments.

It will also be necessary to issue appropriate textbooks.

Shop foreman of an inspection and repair center, com. Zakharov (Chebarkul', Chelyabinsk region), supports the suggestion of establishing special trade schools for training mechanics in the repair of weighing equipment.

The weighing equipment plants should freely sell spare parts (prismatic and knife-edge bearings, pans, levers, etc.) to the establishments which use such equipment. This measure, together with the delegating to the Inspection and Checking Points (ICP) of checking the weighing equipment (along with checking of instruments for linear and angular measurements), should free the establishments from costly outside technical inspection.

Com. Pal'chik writes that the staff of the "Vesomerpribor" plant (Kishenev) services the whole of Moldavia, but does not, of course, manage to do it properly. The quality of repairs is poor, and the cost is 2-3 times greater than normal. The overhead expenses are also large.

The transfer of the repairs to the Technical Repair Centers would be advantageous both to the State and the collective farms. If the TRCs are supplied with standard measuring instruments they will be in a position to carry out any repairs to scales and weights. The TRCs should also be entrusted with the supply of weighing equipment to the collective and state farms and other rural organizations. This can be certainly achieved even without any special personnel. The Technical Repair Centers have good technical personnel. Specialists for weighing equipment repairs could be trained by sending some of the TRC personnel to monthly training courses.

In bringing to the notice of its readers the comments on S. I. Gauzner's article the editorial board of this journal considers that the questions raised by the contributors deserve further discussion by a wide circle of specialists and requests its readers to take an active part in the discussion.

IMPROVEMENT OF THE WORK OF ADMINISTRATIVE INSPECTION AGENCIES*

N. M. Latovich (V. I. Lenin Khar'kov Polytechnical Institute) considers that the questions raised by B. N. Vorontsov deserve serious consideration.

The transfer of the functions of shop production inspection in certain spheres to the production personnel will undoubtedly lower the cost of production by dispensing with the inspection personnel. The inspection operation which can be transferred to the production personnel should be selected by the management of the shop Technical Inspection Bureau (TIB) in conjunction with the shop management and the inspection laboratory. The people who will be responsible for the quality of technological inspection should be prepared for the job in advance.

The participation of the inspection laboratories in organizing the new method of inspection and in the technological production process should not lead to the displacement of the (TIBs) inspectors and the production personnel by inspection laboratory workers and to the weakening of their supervision of the state of the measuring equipment.

The participation of the inspection laboratories in the technological production process should amount to the inspection of the right use and assignment of measuring equipment, to technical training in the art of measurements, to routine inspection of the quality of production, to supervision of the condition of measuring instruments, to helping to analyze the reasons for scrap, to working out new methods and means of inspection, to introducing new measurement techniques, etc.

In order to improve the technical level of production it is advisable to assign trained inspection laboratory workers to certain production spheres. These workers will not only be able to supervise the condition of the measuring equipment used in production and acquire technical experience, but will also take an active part in solving measurement problems which arise in the course of production.

It would be advisable to subordinate the shop Technical Inspection Bureaus, in questions of measurements, to the central inspection laboratories. This would lead to a joint effort in solving pressing problems of improving the measuring technique on the spot under production conditions, to the combination of supervision over the measuring equipment and the quality of technological production control, and it would bring the metrologists and measurement technique closer to the production processes.

The workers of the Central Inspection Laboratories should initiate the raising of the technical level of inspection and supervision. No extra rights need be granted to them for this purpose. Full utilization of the existing instructions on the right and duties of the factory inspection agencies and a meticulous execution of their duties by the Central Inspection Laboratories will raise their competence.

The question of setting the times for routine inspection of instruments by the Central Inspection Laboratories and holding personnel using the instrument responsible for interim inspections is also pertinent.

The assigning of gages to individual workers is only of value in large scale mass production, when the worker is on repetition work and uses the same gage for a long time at a stretch. The granting of the right to the workers themselves to set the time for gage inspections is not advisable since this will lower the responsibility of the laboratories for the condition of the measuring equipment and weaken the part they play in general production. The setting of the checking times of the measuring equipment requires a study of various aspects connected with

* By way of discussion of B. N. Vorontsov's article "Pressing tasks of the Administrative Inspection Agencies" (Measurement Techniques, No. 5, 1958).

the premature wear, assignment and use of the instruments. Hence the inspection times should be fixed by the inspection laboratories.

The question of selecting, training and using the personnel of inspection laboratories requires serious consideration. Other inspection laboratory workers are not used according to their qualifications and the better-qualified ones are transferred elsewhere.

I. A. Kuptsov (Kuibyshev) notes that the formula "the worker is the best inspector of the quality of production" should become the starting point in reorganizing the administrative inspection of the measuring equipment used in production.

The transfer of the inspection operations to the worker places a great responsibility on him for the quality of production, disciplines him, and makes him observe strictly the technology of production and at the same time become critical with respect to the production technology.

The assignment of gages to individual workers and granting them the right to determine the inspection time for the gages raises a problem for the administrative inspection agencies (the Central Inspection Laboratories and Inspection and Test Points) which should not only supervise the correct use of the measuring equipment, but also provide the workers with the necessary knowledge of such questions as the basic metrological properties of the measuring equipment and the effect of physical factors (temperature, difference in the linear expansion coefficients, etc) on the accuracy of measurement.

Among the other questions dealt with in the article the problem of the formal approach to the evaluation of the serviceability of the instruments deserves attention. The amount of wear in the working surfaces of micrometers and slide gages should be evaluated from the point of view of the required accuracy of the details to be measured.

In compulsory checking and inspections at the various establishments, workers of the State Inspection Laboratory should evaluate the serviceability of the instruments according to the accuracy required of them.

The measures with respect to the improvement of the administrative inspection suggested in the article will provide the possibility for the inspection laboratories to study more deeply scientific and research questions in the sphere of measurements, to develop measuring methods, determine the errors in special measuring devices. made in large quantities by the plants, etc.

The 3rd Leningrad Scientific and Technical Conference on Problems of Interchangeability, Accuracy and Inspection Methods in Engineering (1957) noted that the technique practised by the metrological organizations in working out results of measurements is obsolete and does not correspond to modern theory of errors in production measurements. It was recommended that the modern theory of errors for a small number of measurements be used.

In order to prepare for the reorganization of the factory administrative inspection it is advisable to call a conference of the heads of administrative inspection agencies, State Inspection Laboratories, and representatives of councils of national economy for discussing the leading role of the councils of national economy in the organization of the administrative inspection agencies, the conditions of work and the state of the Central Inspection Laboratories, the methods of working out the test results, etc.

Manager of the "Strommashina" plant Technical Inspection Department (Kostroma) I. V. Kiselev writes that at the Kirov plant in Leningrad, the Gor'ki automobile plant, the Vakhrushev Tomsk plant.and others, a new system of inspection has been adopted which eliminates interprocess inspection. The components are stamped by the workers themselves. The Technical Inspection Department only inspects at the end of the conveyor line for appearance and the presence of a stamp.

When the interprocess inspection is transferred to the workers they are also assigned gages. The workers are responsible for the condition of the gages. The condition of the measuring equipment is checked by the foremen who are also obliged to check the quality of production (first component). They have at their disposal simple means of determining the serviceability of gages (sets of three block-gages for checking snap gages, reference standards for zero and working scale instrument settings, etc).

The Central Inspection Laboratories' work is reduced to the supervision of "personal" gages by means of check inspections in the shop.

The times of inspections fixed by the Central Inspection Laboratories cannot completely guarantee the serviceability of gages for the whole period between the routine checks, no matter how often they are made. A lot depends on the conscientiousness and experience of the workers themselves and the exacting attention paid by the storekeepers who issue the gages.

In the opinion of the head of the Technical Inspection Department V. V. Gretsov (Tula) the problems of improving technical inspection should be widely discussed at technical factory conferences and councils and in the daily and technical press, with the participation of social organizations.

Some of the interprocess inspection could be transferred to the production workers themselves and the Technical Inspection Departments provided with all the required equipment for testing, inspection, acceptance and dispatch of the completed products. The transfer to the production workers of some of the Technical Inspection Department's functions will lead to a simpler structure of the department; will free a large number of inspectors, foremen inspectors, and workers of other categories, and provide a more efficient distribution of personnel according to the production requirements. The responsibility of the production workers for the quality of production will also increase.

The lack of a desire to improve the work of Technical Inspection Department is often caused by unjustified overcautiousness.

The Central Inspection Laboratories must be brought closer to production but they must be left under the control of the Technical Inspection Departments so as to observe strictly a unified system of measures at the plant. In conjunction with the technologists the Central Inspection Laboratories must organize and introduce the new progressive forms of inspection.

The Technical Inspection Departments and the Central Inspection Laboratories must be supplied with experienced specialists. The difference in pay between similar workers in the Technical Inspection Departments and Central Inspection Laboratories on the one hand and production workers on the other must be abolished.

The supply of spare parts to the Technical Inspection Departments and the Laboratories and their stock of test gear and other devices must be improved. For instance the use of universal measuring microscopes UIM-21 and UIM-22 is limited only due to the fact that the plant in question for some unknown reason supplies auxiliary equipment only "on special order." The catalogues for these instruments also require revision.

ACCURACY OF A MEASURING INSTRUMENT*

I. G. Entis considers that it is impossible not to agree with V.P . Radovitskii on the necessity of introducing a unified conception of the accuracy of a measuring instrument and of standardizing the accuracy grades. He suggests to represent grade (k) and sub-grade (n) of measuring instruments with respect to error δ by the percentage expression

$$\delta = n \cdot 10^{-k}\ \%.$$

In each grade there should be 5 sub-grades according to the normal series 1.0, 1.6, 2.5, 4 and 6. The designation of the accuracy grade and sub-grade should be made in the following manner:

k[n], for instance, an instrument with a relative error of $\delta = 0.025\% = 2.5 \cdot 10^{-2}\%$ is of the grade 2[2.5], and an instrument with $\delta = 0.04$ is of grade 0[4].

*By way of discussion of V. P. Radovitskii's article "Accuracy of a measuring instrument" (Measurement Techniques, No. 4, 1957).

I. G. Entis assumes that instruments should be characterized by accuracy grades only instead of being also subdivided into categories, as it is done in the checking technique.

P. Ya. Nedviga agrees with V. P. Radovitskii that it is logical to take as a measure of the accuracy of instruments the reciprocal of the error, he does not recommend, however, to introduce the concept of an index of accuracy. The decimal point up to which the measurement is accurate should be taken as the grade of accuracy. Thus a measurement made with an error of 1.5% should be called a measurement with an error of 1.5 units of the second grade.

P. Ya. Nedviga considers that it is not enough to classify the degrees of accuracy, it is necessary to standardize the concepts of the correctness (accuracy) and reliability of measurement. I. I. Goncharov expresses the same point of view. He suggests that a concept of "index of accuracy" and "index of reliability" be introduced.

The index of accuracy $\tau = 1/\delta$, where δ is the limiting relative error of the instrument expressed in percentage. By the term limiting error he means three times the mean square error under normal operating conditions.

The reliability index $T = 1/\Delta$, where Δ is the basic total (systematic and random) relative error in percentage.

Thus the accuracy index characterizes the reproducibility of the measurement including all the required corrections, and the index of reliability characterizes the limit within which lies the value of the measured quantity when the instrument is used without corrections.

The response to V. P. Rodovitskii's suggestions shows that he has touched upon an interesting question which should become the subject of wide discussion.

TRAINING OF STATE INSPECTORS

I. P. Kolmakov

Training of personnel for measurement equipment inspection at the State Inspection Laboratories, especially laboratories of the third grade, is of primary importance. Their personnel must be familiar with all the testing done by laboratories of that grade.

Often State inspectors both in temporary and urban branches, have to test by special request from establishments instruments used not only for mechanical but also for electrical, thermal, linear and angular measurements. If the inspector has a slight training only in one of these types of measurements, the laboratory is obliged to send out for this work 2-3 inspectors instead of one. A laboratory of the 3rd grade which has only a small personnel cannot send out so many people at the same time.

Formerly the personnel for state inspection was trained at special courses run by the Committee of Standards, Measures and Measuring Instruments. The students received a wide theoretical and practical training which was not inferior, in our opinion, to the standard of the Odessa Training School of Measurements. The students obtained the grade of state inspector after a prolonged practical experience in the laboratory not only in one type of measurement, in which they specialized, but also in other types of measurements and in conjunction with the study of other subjects. Every inspector who completed these courses was familiar not only with applied metrology but also had a wide knowledge of other theoretical questions. Such a training produced good results especially for laboratories of the 3rd grade, where inspectors often have to work independently.

At present, the State inspection laboratories for measurement equipment accept people with a secondary technical education who must after independent work in the laboratory pass an external examination at one of the Committee's Institutes, thus obtaining the grade of inspector. It must be stated that the training of these people in the State Inspection Laboratories differs greatly: there is no recognized syllabus or recognized method and the Committee's Institutes do not render any assistance. As the result of this, the newly accepted personnel study in

the laboratory during the allocated time, or study on their own. This system is unsatisfactory, and often a good worker with a secondary technical education becomes subject to dismissal because he has not passed his examination.

The personnel of the Vologda State Inspection Laboratory suggests that the former training should be restarted with one of two courses per year. This would provide an opportunity for the 3rd grade laboratories to train their personnel with a secondary technical education who would eventually replace those without that education. It would do no harm for workers with higher education also to attend these courses.

The state inspectors' courses should deal in detail with the following subjects: inspection of the condition of measuring equipment and the observation of standards and technical specifications; study of the technical and operational properties of measuring instruments; application of the latest measuring technique in production, and other questions connected with the work of local branches of the Committee which would help to solve the problems facing these branches. It would be interesting to find out the opinion of other laboratory workers on this subject.

CHECKING THE STRENGTH-OF-MATERIALS TESTING MACHINES

B. V. Gnilitskii

In connection with the increasing testing of the strength of materials in many branches of industry, there arises the necessity of solving certain problems in connection with the checking of machines used for strength-of-materials testing.

The machines used in our country have several defects. They are not supplied with grips for the dynamometers with which they are checked. Hence, whenever checking is to be done, the owner of the machine must urgently make these grips, which disturbs the working procedure in the laboratory and causes loss of the tester's time. The hydraulic machines are fitted with tractor instead of special pumps. These pumps do not supply the oil evenly and make a loud noise.

The manner in which these machines are repaired deserves special attention. Many of them, especially the foreign ones, have been working for several decades and have been repaired several times. However, the repairs amount to the washing out of the bearings, removal of scorings, and burrs, checking or manufacture of new racks for the force measuring mechanism, changing of the weight of the pendulum or detachable weights. The pistons, cylinders, the working surfaces of beams, reduction gears and columns, despite their wear and occasionally considerable damage, are not repaired. The graph mechanisms are in the majority of cases not repaired and sometimes completely removed. All this is explained by the fact that there are no spares available and it is not always possible to make new parts. But even these repairs become a most complicated problem if the machines are in a different town from the repair shops. Instances when the repair crews arrive a year after they have been requested to come are not rare.

Since the testing of materials is not included on the list of compulsory inspection, the State Inspection Laboratories are only interested in the stamp on the manometer and pay little attention to the fact that the manometer is not suited for the purpose or that it has been fixed without consideration of the grade or accuracy required, the size of the division, or the range. In recent years there has been the tendency to supply manometers of the 0.5 and 0.35 grade. These manometers, however, are soon put out of commission, since their mechanism is subjected to a violent shock at the instant the sample is destroyed and the pressure falls to zero.

In addition to removing above defects it is advisable to clarify the following questions.

Since the permissible error is established at ±1 and ±2% of the measured effort, it is logical to divide the machines accordingly into grade 1 and 2. At the same time a rule should be established that the repaired machines should be of grade 1 and those in use certified as grade 2.

According to the existing specification the smallest measured effort (and hence the operating effort) must be not less than 0.04 of the maximum effort developed by the machine. Nothing, however, is said about the double-plunger machines in which the piston serves at the same time as a cylinder for the smaller (inner) piston. For instance, in machine UG-20/2 the 20 ton · cm and 10 ton · cm scales correspond to the large cylinder, and the 4 ton · cm, 2 ton · cm and 1 ton · cm scales to the small cylinder. If 0.04 of 20 ton · cm is taken, the smallest point will be 800 kg · cm and the scale of 1 ton · cm becomes redundant. In fact the measurement error of the machine even with a load of 100 kg · cm does not exceed $\pm 1\%$: which is lower than 160 kg · cm, the lowest point for the 4 ton · cm scale, i.e., 0.04 of 4 ton · cm. Moreover the entire 1 ton · cm is being used.

It would be more correct to take 0.04 of the scale corresponding to each cylinder and regard the checking of a double cylinder machine as two separate machines.

In order to bring some order into the checking and use of machines for testing the strength of materials it is necessary to:

establish the limit for the wear of such important details as the cylinders, pistons, operating surfaces of beams, and racks for the force-measuring mechanism,

to include the machines for testing the strength of materials in the compulsory inspection list,

to install on the presses grade 1.5 manometers with a value of divisions and measuring range corresponding to the measured efforts,

to install a device protecting the above manometer from damage due to a sudden drop in pressure.

IMPROVING THE CONSTRUCTION OF MEASURING INSTRUMENTS

M. F. Kolosova and N. A. Tkalenko

In order to improve definition and establish better working conditions in the universal measuring microscope UIM-21, the white lighting of the projection attachment should be replaced by a green light (similar to that in the telescope caliper).

The projection attachment should have an opening for the reading microscope on one of its optical axes (nearer to the screen). This will permit the operator to work standing up.

For further modernization of the microscope and the attachment, it would be advisable to arrange for the fixing of the projection attachment without removing the eyepiece.

In order to prevent rapid wear of the surface of cranks over which the carriage bearings run it is advisable to enclose them.

In the internal measurement devices of the measuring machine IZM-10 low quality agate inserts are fixed in the links, the lifetime of these inserts is very short. The checking of 8 to 10 reference rings wears out the sphere in the inserts. The same applies to the links for measuring internal dimensions on a horizontal telescope caliper.

It would be advisable to include in the set of spheres, balls for the indicator heads of the clockwork type; and for the lever indicator heads, levers with a measuring end piece.

It is necessary to supply an additional set of setting feet in the box of dial inside-calipers.

In future it is advisable to make, on special order, devices for checking end gages on a measuring machine, devices for checking optical dividing heads, and stands with indicating supports for optical dividing heads.